THE IGUANODON—A BIRD-LIKE REPTILE.

FROM Dr. Henry Woodward, F.R.S., P.G.S., of the Natural History Museum, we have received the following interesting account of the iguanodon:

There has just been set up in the British Museum (Natural History), Cromwell Road, a restoration of the entire skeleton of one of the most remarkable of extinct giants that peopled the earth in the Wealden period, an epoch marked by relics of old land surfaces just preceding the age of the chalk. It is seventy years ago since Dr. Mantell first discovered the remains of a huge reptile in the Hastings sandstone, which from the resemblance in its teeth to a living vegetable-feeding lizard—the iguana—he named iguanodon. Numerous bones and many teeth have since been found at Maidstone in Kent, in the Weald of Sussex, and the Isle of Wight, but no complete skeleton was ever obtained, save in Belgium. A fancy restoration of the creature, as a quadruped, with four toes on each foot, was set up by Waterhouse Hawkins, and may still be seen in the grounds of the Crystal Palace. But its fossil footprints on the Hastings sandstone showed that it had only three toes to its

RESTORED FIGURE OF THE IGUANODON.—SKETCHED BY MISS ALICE B. WOODWARD.

The animal is shown in the attitude in which it usually walked. The fore limbs are much shorter than the hind limbs, which are very powerful, having three toes to each foot and the same number of joints as in a bird's foot. The ponderous tail no doubt gave support to the animal when in an erect position, and was also used in swimming.—Illustrated London News.

foot, and that it must have walked on its hind legs, as it left only a single bipedal track behind. In 1878 no fewer than twenty-five skeletons of iguanodons were discovered at Bernissart, Belgium, entombed in a natural crevasse, now entirely filled by deposits of later date, but which was an open valley of the Wealden period cut out of the carboniferous rocks that formed the old land surface, at that time clothed with a vegetation of cycads, of ferns, and Equiseta. Fresh water tortoises and large fishes with enameled scales inhabited the river, while crocodiles, lizards, and giant iguanodons frequented its banks.

The iguanodon was a vegetable feeding animal, and its cheek teeth, which exceed eighty in number, were well adapted for chewing the leaves and shoots of plants on which it fed. It had no front teeth, but a horny beak like that of a turtle. The fore limbs are shorter than the hind ones, the former being 6 ft. and the latter 9 ft. long. The hand had five digits, with nails, and the thumb was armed with a conical sharp-pointed spur. The hands appear, from their shape, to have been ill adapted for walking. The hind limbs were large and very powerful, and had three toes on each foot, with the same number of joints as in a bird's foot—namely, three to the inner toe, four to the middle, and five to the outer toe. The bones of the pelvis also closely resemble those of wingless birds, such as the emu and dinornis. The ponderous tail, as well as the back, was strengthened by numerous bony fibers, which no doubt gave support to the animal when in an erect position; it also assisted it greatly in swimming. The skeleton measures 15 ft. in height and 30 ft. from the head to the tail; it is set up in the position in which it is considered the animal usually walked. The iguanodon is a good example of that singular class of extinct reptiles, the Dinosauria, from which it is believed that our modern birds were derived.

The British Museum of Natural History is indebted to M. Dupont, the Director of the Brussels Museum, for the opportunity of acquiring by exchange this very interesting reproduction; the originals are all preserved there, and have been admirably described and figured by M. Dollo. The restoration and reconstruction were carried out by M. Depauw, another member of the staff of the Brussels Museum.—*Illustrated London News.*

THE FOURTH EDITION OF DANA'S MANUAL OF GEOLOGY.

THE successive editions of a great work of reference furnish the history of the advance of knowledge. Like the variously formed stories of a building, they mark the stages of its completion. The present decade has been signalized by the production of dictionaries, encyclopedias and manuals, and it is an instructive study to compare the contents and proportions of their latest issue with their predecessors. Nothing more clearly announces the industry of mind. It is true that much of the new matter consists of the filling in of detail or the extension of observations along lines already strongly drawn. But with allowance for all this, essentially new material in large quantities has engaged the labor of the revisionist, and has added many pages to his volumes of instruction.

The new edition of Professor J. D. Dana's "Text Book of Geology" naturally challenges attention. It has become established as the leading text book of the science, at least for American students, in spite of the striking merits of similar works by Geikie, Prestwich, Credner, Phillips, Green and Le Conte. It treats of a science in which America boasts of the foremost thinkers and the most zealous explorers. The new conceptions introduced by the original and picturesque treatment of geological subjects by American writers make any new epitome of them notable. And it is no less significant on the score of new facts, for in all its divisions, dynamic, structural and historical, American geologists have gathered from the wide range of geological phenomena in this country an extraordinary volume of observations. It is true, also, that illustration and arrangement have improved in thoroughness and method, and the new text books are symptomatic of that advance in mere book making which distinguishes this age of literary enterprise. Professor Dana's Text Book of Geology has always been a model in its suggestiveness as a type. The divisions, the coarse and fine letterpress, the subordination of detail to general views, the thoroughness of the index, and the simplicity of style have made it the most effective medium for geological instruction which we have.

The comparative size of the third and fourth editions of this text book afford at once a suggestive criterion of the expanded contents of the latter. In the third edition there are, exclusive of index and appendix, 770 pages, and in the new, exclusive of index, 1,036 pages, an increase of over forty per cent., while if we look for the portions to which this enlargement is to be assigned, we find it almost limited to dynamical and historical geology. The third edition was published before the consolidation of the various United States surveys, and the wide and exhaustive scope of the monographs, bulletins and annual reports of the present survey were not then thought of. A recapitulation of these alone would afford ample reason for the thickening of any text book of geology not previously cognizant of their results. The great number of separate and independent essays and studies and a more considerate recognition of paleontology has added more material, and in some sections made the later edition a practically new work.

A manual of any kind should be, if constructed for the widest usefulness, free from the intrusion of personal views, or the defense of theories which hold only a provisional tenure. It is therefore modeled or written upon a design of judicial fairness. The suppression of the author, so far as he has involved himself in the polemics of science, is approximately complete. The notice, however, of such a monument of industry as this fifth edition of the Text Book of Geology, written by so fervent a thinker and distinguished an investigator as Dr. Dana, naturally draws its interest from reference to such opinions as the author of the manual still reveals on subjects and discussions with which his name has been associated, or which challenge some sort of judgment from authority. Dr. Dana has always been keen and strenuous in debate, and

has felt a personal interest in the welfare and permanence of certain geological positions. We instinctively turn to the pages of this great contribution to geological knowledge for an expression of some final decision on these topics, the more eagerly as Dana was not a narrow constructionist who values consistency over truth and progress. And furthermore it is inevitable that we should search among its pages for his relation to the great and variously interpreted fact of evolution.

To the writers and workers in geology of the last fifty years the questions connected with metamorphism have been very familiar, and the answers have been various. The subject has been connected with a great many considerations of a chemical, mineralogical, and dynamic character and the arguments and debates have reflected in their various participants special lines of study. The subject meets one on the threshold of geology as the rocks by which it is illustrated are among the earliest in the chronological scheme of the earth's strata. The gneisses, schists, slates, marbles, are types of metamorphic action and, if originally sediments, their present crystalline condition, with their diversified mineral contents, presents a peculiar geognostic problem. The metamorphic action of igneous rocks and the extension of metamorphic action much higher in the geological series have been in late years more and more emphasized.

It was in connection with the question of metamorphism that the name of Professor Dana came into some prominence, from his pronounced opposition to the views of Dr. T. Sterry Hunt. The address of Dr. Hunt before the American Association for the Advancement of Science in 1871 dwelt upon this vexed question and appeared to formulate a theory of this sort, viz., that while the crystalline schists might owe their origin partially to compression, heat, and the chemical rearrangements and crystallizing agencies induced by these, they largely represented chemical reactions, by which the "silicates of magnesia, lime and iron which are the sources of the serpentine, chrysolite, pyroxene, hornblende, steatite, and chlorite," have been, or might have been, "formed in basins at the earth's surface, by reactions between magnesian solutions and

THE IGUANODON.

dissolved silica." He further said in that section of his address on the "Origin of Crystalline Rocks" that to explain the generation of silicates like the feldspars, scoopolite, garnet, and saussurite he suggested that double aluminous silicates, allied to the zeolites, might have been formed, and subsequently rendered anhydrous." He seemed to place his views in sympathy with the hypothesis that "the elements of the various rocks were originally deposited as, for the most part, chemically formed sediments, as precipitates; and that the subsequent changes have been simply molecular, or, at most, confined in certain cases to reactions between the mingled elements of the sediments, with the elimination of water and carbonic acid." The fundamental and original difference between Dr. Hunt's position and that of Professor Dana, which Hunt somewhat contemptuously designated as pseudomorphic metamorphism, was in their interpretation of the primary sediments from which the schists or crystalline rocks were derived. These were in the conception of Professor Dana ordinary fragmentary sediments gathered from pre-existing rocks and deposited in strata of arenaceous, argillaceous, and mingled character, to be subsequently by thermo-dynamic influences transmuted into slates, sandstones, and schists. Dr. Hunt regarded these early sediments as largely precipitates, and invoked chemical agencies to prepare them, their chemical constitution, thus secured, limiting or determining the mineralogical features of the rocks derived from them.

If we turn to the pages of this fourth edition of Dana's Manual of Geology, we find an expanded and elaborate treatment of the subject, in which the outlines of his first contention seem little changed, but in which the details, with its illuminating examples, derived from modern investigation, are greatly re-enforced. Dana defines metamorphism then as meaning change. "In geology it is change in texture, crystalline structure, or mineral constitution; as when a common limestone becomes crystallized, and thereby converted into statuary marble, or as sandstone into gneiss or granite, or an augitic rock into a hornblende rock, or a massive rock into a laminated or foliated

kind." Again, "the rocks that have become changed into metamorphic rocks are for the most part fragmental rocks, as sandstones, shales, conglomerates, with the limestones. These, according to their various constitutions, have been changed to gneiss, granite, mica schist, and the several other kinds of schist; and this change has been the chief method of origin of the schists."

Heat, both that derived from the earth's interior and, more importantly, that originating in the movement over each other of the rocky strata, upheaved, plicated, and twisted by continental disturbance, or crustal shrinkage, and disseminated moisture, with pressure, are the effective causes. The minerals developed depend upon the chemical ingredients of the rocks or sediments, and the point of fusion reached, by which, in the fullest sense, chemical affinities are given free play, within the limits of the amounts present of different elements. The heat may have been comparatively low, as 500° to 1,200° F., and the process of change may have been extremely slow. Van Hise and Irving and others have made prominent the endogenous changes which are constantly going on in rocks by which their crystalline contents are altered and their chemical constitution modified. Moisture derived from the absorbed moisture of rocks, which would be changed to steam at the temperature of metamorphosis, is regarded as adequate to initiate and complete the mineral changes noticed in metamorphic rocks.

Metamorphism is separated into kinds or phases—1, incipient, the first and lowest stage of thermal action; 2, crystalline or that in which there is simply change in crystallization; 3, paramorphic or change in crystalline form and not in composition, as pyroxene to hornblende or aragonite to calcite; 4, metachemic when there is a change in chemical constitution; 5, endocrystallic or effects of pressure in modifying the structure of crystals or in fracturing them.

There is here no substantial change from the views expressed in the former edition of the manual, but the discussion is more luminous and the illustrations greatly improved.

On the absorbing question of evolution, which both in theory and experiment has reached a point which it cannot seem to pass, where demonstration fails of conviction, though it seems to make some process of evolution inevitable, Dr. Dana has this to say.

Professor Dana expresses himself comprehensively in regard to the question of evolution. He admits development, a process of progressive betterments, or stages of ascension in the animal and vegetable worlds, and he invokes the principle of Lamarck—inherited variations produced by regional adaptation—and also that of Darwin, less markedly—survival of the fittest—as operative in the change. But he draws attention to the fact that there is an organic tendency involved in these changes, and that something like a vis a tergo, or perhaps more crucially a vis in se, animates the spectacle of evolution. He quotes Gaudry's observations upon the similarity of generic and specific forms in widely separated regions, and Gaudry's conclusion that migration does not, or is not likely, to furnish a complete explanation of their resemblance.

Dr. Dana does not accept, willingly, the Darwinian hypothesis. He argues that natural selection derives its experimental proof from artificial selection, and that in such cases permanency of variation is not attained. But "in wild nature variations are, in general, the slow and sure result of the conditions—the organic conditions, on one side, and the physical and biological, on the other; they should occur, generally, in a large part of the associated individuals of a species; and being nature-made, the results are permanent. When, therefore, a variation appears that admits of augmentation by continued interbreeding, progress should be general; and the unadaptable few should disappear, not the 'multitudes.'"

The change is acknowledged, and adaptation directly abetted it, but natural selection is not considered an adequate raison d'etre. Professor Dana alludes to his own theory of cephalization, by which increasing nervous development and ganglionic concentration accompanies advance in structure.

To allude to the many excellencies of this work, its judicial poise of judgment, the large addition of fact, reference and illustration would enlarge this notice to the most unreasonable proportions. We have glanced at two points of interest which would perhaps, to most scientific readers, first challenge attention.

This remarkable work left the hands of its author but a short time before his death. It remains the most permanent monument to his industry and learning, the most eloquent tribute to the range and justice of his scientific views.   L. P. G.

THE PLACE OF IRON IN NATURE.

By JOHN T. KEMP, M.A.Cantab.

FEW elements are more abundant in nature than iron, while none is more widely distributed. Its compounds pervade every portion of the earth's crust. Among massive and stratified rocks alike, ferruginous deposits exist on an enormous scale, frequently assuming mountainous dimensions or covering many hundred square miles. The variety of their composition is hardly less remarkable. Thus the useful ores include ferric oxide (Fe_2O_3), known in the crystallized condition as specular iron ore and in the amorphous state as hematite; the magnetic oxide (Fe_3O_4), or magnetite; ferric hydrate (Fe_2O_3+water), which occurs sparingly in the crystalline form as the mineral gothite ($Fe_2O_3.H_2O$), but abounds in the amorphous condition of limonite ($2Fe_2O_3.3H_2O$, but probably a mixture of several hydrates); titaniferous iron, a mixture of ferric oxide with a variable proportion of titanic oxide (TiO_2); ferrous carbonate ($FeCO_3$), or spathic iron ore, with impure varieties known as clay ironstone. To these must be added iron disulphide (FeS_2), of which two crystalline modifications occur, viz., iron pyrites, commonly met with in the form of brass yellow cubes, and marcasite, much lighter in color, with a radiated structure. Among less abundant but noteworthy compounds may be mentioned magnetic pyrites (Fe_5S_6); copper pyrites ($Cu_2S.Fe_2S_3$), one of the most abundant ores of that metal; mispickel, or arsenical pyrites ($FeSAs$), the principal source of arsenic; vivianite, a ferrous phosphate of variable composition, met with

in beds in which animal matter has decayed, often of a brilliant blue color.

A few illustrations of the magnitude of some ferruginous deposits may here be quoted. Pilot Knob, in Missouri, a hill seven hundred feet high, consists almost entirely of a single mass of hematite. Near Gellivara, in the north of Sweden, a mountain of magnetite exists, whose dimensions are reported as sixteen thousand feet long, eight thousand feet broad, and two thousand feet high. Beds of magnetite are met with among the Archæan rocks of Canada up to two hundred feet in thickness. In the same region are immense deposits of hematite, titaniferous ore, and iron sulphides. Zirkel describes Erzberg, a mountain in Styria, rising two thousand feet above the neighboring valley, as composed almost exclusively of spathic iron ore.

Besides those ferruginous deposits which from their form or dimensions are entitled to rank as independent rock masses, hosts of smaller aggregations are met with, such as veins, encrusting layers, nodules, and scattered crystals. Thus hematite often occurs in veins traversing crystalline rocks, while layers of ferric hydrate are deposited in their channels by waters containing iron, both above and below the surface. Many of the septarian masses so common in clayey strata consist essentially of clay ironstone. Hematite nodules, often containing fossil remains, abound among some of the carboniferous beds. Masses and single crystals of iron pyrites occur plentifully in some strata, marcasite in others, but what conditions determine the form assumed by the sulphide we do not know. The various "greensands" owe their appellation to the presence of grains of an iron silicate or glauconite; deposits of the same mineral are now forming in certain parts of the sea bed. Magnetite may here be mentioned as an essential constituent of basalt and other volcanic rocks, in which it occurs in the form of opaque octahedral crystals.

The most striking evidence of the universal presence of iron in nature is, however, found in the colors imparted by its compounds. Iron has justly been called "the great pigment of nature." Few deposits there are which are not tinged with iron in one chemical form or another. To it are due the brown, yellow, red, green, blue and creamy tints which in endless variety characterize the vast majority of rocks. Green and blue colorations are produced generally by ferrous compounds, red by ferric anhydride, and yellow and brown tints by ferric hydrates. The presence of other substances, such as carbonaceous matter, largely affects the coloration in many instances.

Probably not more than eight or possibly ten of the elements occur in the earth's crust in larger proportion than iron. The significance of this fact will be appreciated when it is added that ninety-nine out of a hundred parts by weight of the crust are estimated to be composed of some sixteen elements at the most, leaving fifty or more which constitute the remaining one-hundredth part. Nevertheless, in comparison with oxygen, silicon and aluminum, of which about eighty-five per cent. of the accessible rocks consist, a decidedly low place must be assigned to iron as constituting probably less than one per cent. of the whole, so rapidly does the relative abundance of the elements fall off. About half of the earth's crust is composed of oxygen.

Iron is, as would naturally be expected from the universality of its occurrence elsewhere, one of the elements, some thirty in all, which have been detected in the oceanic waters. Messrs. Thorpe and Morton report the presence of ferrous carbonate to the extent of one part in two hundred thousand in the water of the Irish Sea collected during winter. This proportion, if maintained throughout the ocean, would indicate the existence of more than four billion tons of metallic iron in solution.

In the organic world, again, iron appears to play an indispensable part. It is an essential constituent of the blood, while the production of chlorophyl in plants has been experimentally proved to be, in some way as yet imperfectly understood, dependent on the presence of iron in their nutriment. According to Ehrenberg, some species of diatoms secrete ferric oxide in considerable quantities.

But the existence of iron is not confined to our own planet. The spectroscope reveals its presence in the sun and many of the stars. It is also the chief constituent of meteorites.

Native iron is of very rare occurrence among the terrestrial rocks. Veins are all but unknown. It has most frequently been detected in the form of grains scattered through certain eruptive rocks, such as the gabbros belonging to the volcanic outbursts of Mull and Skye during the Tertiary period, and in the basalt of the Giant's Causeway. Nordenskiold has discovered in the island of Disco, off the west coast of Greenland, a number of large masses of iron, one weighing nearly twelve tons; but whether they are of terrestrial origin is doubtful. Similar masses occur in the basalt of the vicinity. The great traveler himself regarded them as memorials of a meteoric fall during the outflowing of the rock in Tertiary times; but Daubrée has shown that the rock contains microscopic particles of iron, associated with certain other minerals in such a way as to exclude the hypothesis of the conjunction being accidental. He therefore concludes that the iron came from below with the other constituents of the mass.

This subject naturally raises the question, so often asked in view of the high density (about 5·5) of the earth as a whole compared with the average density (say 2·5) of the surface rocks, viz., whether the interior contains large quantities of iron or other uncombined metals. Taking as a guide Sir A. Geikie's list of the sixteen most abundant elements, to wit, O, Si, C, S, H, Cl, P, F, Al, Ca, Mg, K, Na, Fe, Mn, Ba, it is observable that their heaviest combinations with one another barely reach the minimum specific gravity required to account for the earth's density. Whether the enormous pressure, vastly greater than any whose effects we can observe in our laboratories, to which the earth's internal layers are subjected, would serve to compress the materials to the requisite degree is exceedingly doubtful, while it is certain that the high internal temperature of the earth's interior must, to a large extent, counteract the reduction of volume through pressure. It seems most probable, therefore, that extensive deposits of heavy materials of some kind exist in the interior of the earth, and of such none is more likely to abound than iron, considering its high rank as a constituent of the crust.

Meteoric iron is known in masses varying from many tons in weight down to microscopic grains. The latter have been detected in the snows of the Alps and the Arctic regions, and caught on board ship in midocean by means of sheets of glass smeared with glycerine and exposed to the wind. Grains of metallic iron abound in the red clay of the Atlantic Ocean, a fact which may be taken as a proof of its slow growth. Meteoric iron is invariably alloyed with metallic nickel. Until recently the natural occurrence of "nickel-iron" (as the alloy is termed, notwithstanding the predominance of the latter element) was unknown except as a constituent of meteorites. Masses of an alloy of the two metals (with other materials) have, however, been lately discovered in the gravel of a stream in Oregon, which differ in some remarkable respects from all meteorites hitherto known. Thus they do not exhibit the peculiar markings, termed "Widmannstatt's figures," when treated with nitric or hydrochloric acid. Josephinite is the name which has been given to the new mineral.

Iron is also found alloyed with platinum. A specimen from Siberia, analyzed by Berzelius, was found to contain 86·50 per cent. of platinum, 8·32 per cent. of iron, together with small quantities of palladium, rhodium, copper and "gangue." Another sample from South America contained, of platinum 84·30 per cent., of iron 5·31 per cent., of rhodium 3·46 per cent., besides palladium, iridium, osmium and copper, seven metals in all.—*Knowledge.*

A NEW KEROSENE ATTACHMENT FOR KNAPSACK SPRAYERS.

PROF. HOWARD EVARTS WEED, of the Mississippi Agricultural College, Starkville, Miss., sends us the following:

The accompanying illustration shows the attachment as now made by the Deming Company, of Salem, Ohio, in connection with their "Perfected Galloway" knapsack sprayer. The kerosene is placed in a separate tank holding one gallon, and which is attached to the main tank by means of clips. A brass pipe connects the kerosene tank with the bottom of the pump in the center of the main tank, and a check valve is placed in the kerosene pipe just inside the

main tank, with a second valve through which the water passes, at right angles to this. These check valves permit the passage of the kerosene and the water into the pump, but prevent any mixture of the liquids except while pumping.

A stopcock is placed in the connection between the kerosene tank and the pump, and attached to it is a rod bent around to the side of the main tank, where it fits into notches on a gage, as shown in the illustration. When the rod is placed in the bottom notch the stopcock is closed, and when in the top notch is fully open, and when in the latter position equal parts of kerosene and water are used.

The notches on the gage plate are marked to indicate the proportion of kerosene which is being used as follows:

5·10, 4-10, 3·10, 2-10, 1-10, 1-15, 1-20, 1-30, 0.

Thus, when one part of kerosene to twenty-nine of water is wanted, the rod is placed to the notch marked "1-30," and when one part of kerosene to nineteen of water is wanted, the rod is placed in the notch marked "1-20," and so on. The rod may be changed from one notch to another at any time, even while pumping, and is held firmly in place until changed by the operator.

When the stopcock is changed from one proportion to another, the last proportion indicated will not be secured until a few strokes of the pump have cleared the mixture already in the cylinder and pipes. The working of this attachment is very simple; the main tank is filled with water, and the smaller tank with kerosene, the gage rod is placed in the notch corresponding to the amount of kerosene wanted in the spray, and the pump worked in the usual manner. The kerosene attachment can be readily detached from the main tank when the pump is wanted for ordinary purposes.

Insects that eat leaves can be killed by spraying or dusting the leaves with Paris green and similar poisons, but all insects which suck the juices of plants or the blood of animals can be killed only by the application of some substance like kerosene directly to the insects themselves. Although poisons like Paris green are not applicable to insects which take their food by sucking, yet an external irritant, like kerosene, is applicable to all, and it matters not how they take their food. Kerosene can be used against all insects except those living in confined places where they cannot be reached, such as tomato worms, those living in stored grain, etc. The amount of kerosene which should be used will vary with the kind of insect to be treated, some requiring a much larger proportion than others. Nearly all plants will bear one part of kerosene to ten of water, but when a stronger application is to be made, it should first be tested on a few plants to see if the foliage is affected. For the treatment of ordinary insects the following proportions are recommended:

Plant lice, of all kinds, 1·20.
Caterpillars or other larvæ exposed on leaves, 1-15.
Scale insects on leaves, 1-10.
Scale insects on bark, summer treatment, 3-10.
Scale insects on bark, winter treatment, 3-10.
Lice on domestic animals, except hogs, 3-10.
Lice on hogs and ticks on cattle, 5-10.

The mixing of the two liquids takes place partially in the pump, but more largely in the nozzle, where they are divided into very fine particles. Of course a mixture made in this way is not a permanent one, nor is it necessary that it should be so. What is needed is simply a dilution of the kerosene so that it will not cause injury when applied, and the attachment accomplishes this object fully.

Heretofore, when kerosene has been used as an insecticide, it has been necessary to make it into an emulsion by mixing it with soapsuds, which is a complicated operation requiring considerable care, but with this attachment no care is needed except to see that both tanks are kept filled, and the gage rod in its proper place. The attachment adds about two dollars to the cost of the pump, but more than doubles its value.

THE IMPERIAL FAMILY OF JAPAN.

THE present emperor and empress of Dai Nipon are, without question, two of the most striking figures in modern history. The emperor was born but a little more than a decade and a half before the restoration, and he and his royal consort were reared in that strict seclusion obligatory upon families of rank under the old regime. The celebration of their silver wedding on March 9, 1894, and the general magnificent festivities attending the anniversary throughout the length and breadth of the island empire, remind the thoughtful observer of the remarkable changes that have taken place among the people of that country within the quarter of the century just ended.

When Mutsu Hito came to the throne of his fathers, February 13, 1867, he was a lad not yet sixteen years of age, having been born in Kioto Palace, November 3, 1852. He was a mere boy, with no knowledge whatever of the world, and had lived his short life in that complete isolation which had been the fate of imperial princes for ages. He had been taught the Chinese classics, how to write poetry and how to arrange flowers according to the elaborate system of the Japanese, and how to conduct that most punctilious, perfunctory and elaborate tea ceremony, the cha-no-yu. Not a very good foundation of character for the ruler of more than forty million people, with which to begin his reign, truly! But his conduct from that time has shown that, in spite of his education and the rigid sequestration of his early life, he is a man of great force of character, with a mind ready to receive and assimilate new ideas. It must be remembered that until 1868 the Emperor of Japan was considered the spiritual ruler of the people, and so sacred that none might look upon his face and live; that the people worshiped him as a god; that when he granted an audience, which was very seldom, his face was veiled from the visitor, who must stop a certain distance away from the dais whereon the Mikado squatted; that he was never allowed to wear the same garment twice, nor to eat off the same dish a second time, both clothing and china being destroyed at once. When one bears these things in mind, will the present position and condition of the imperial family of Japan seem like a modern Arabian Nights tale.

For more than two hundred years the Togugawa family had usurped the temporal power of the Mikado, and arrogated to themselves the privilege of ruling the island empire. Little by little, the Shoguns, being soldiers and at the head of feudalism, had gathered to themselves all the rights, privileges and perquisites of the Mikado.

They left him his title, however, the reigning Shogun being content to call himself the Little Tycoon. Mutsu Hito is the hundred and twenty-first ruler of his line, and claims an unbroken descent from Jimmu Tenno, the Son of Heaven, who ruled Japan 660 B. C. He came into power just at a time when the country was ripe for freedom. The door of Japan must be opened; the knocking from within was quite as imperative as had been the dictatorial rat-tat-tat of Commodore Perry from without. He was soon after called upon by a portion of his subjects to place himself at their head to wage war with the Little Tycoon, who had kept the Mikado in the background while he tried to make treaties with foreign countries, who knew not that Japan had any other ruler than the Shogun at the head of the army, in whom was vested all temporal power.

From the strictest seclusion, forth he came, this nineteenth century Mikado, into the broad light of day, the glare of which must have at first half blinded him. In 1868 the Shogun resigned and retired to the quietude of private life, the various wars were ended and the restoration complete. The emperor, at this time, in view of the new duties involving upon him, received the envoys of foreign countries at his palace in Tokio. He was the first Mikado ever to appear in person at a state council; boy that he was, he took an oath before the court nobles and daimios that he would become an actual ruler of his people, and promised that a deliberative assembly should be formed, that all measures should be decided by public opinion, that the uncivilized customs of former times should disappear, and that the impartiality and justice displayed in the workings of nature should be adopted as the basis of action; and, furthermore, that intellect and learning should be sought for throughout the world in order to establish the foundations of his new empire.

After this meeting he traveled from Kioto to Tokio, the new capital, in a gold-lacquered norimon, or closed litter, borne on the uplifted palms of relays of coolies. Only members of the royal family were allowed to be carried in this way; the kaga, which is used by ordinary folk, is carried on the shoulders of the coolies.

In 1869, a little more than a year after he ascended the throne, Mutsu Hito married Haruko, the present empress. She is the daughter of Ichijo Yakada, a noble of the highest rank. The emperor, no more than his humblest subject, is allowed to make a "love

match," unless by some happy chance he fall in love with the woman chosen for his wife. From the daughters of the highest five noble families he may select a consort to divide with him the honors of his position. He may not take an empress, or Hogo-sama, as she is called, from any branch of the imperial family. The reason of this is not quite plain to the outsider. The marriage ceremony was so private that no one can say anything about it. One writer asserts that it was solemnized by some Shinto rites within the temple of the palace, but in such a sacred and peculiar manner that no Japanese even conjectures its form. The emperor may have eleven concubines, if he chooses, and their position is recognized and perfectly reputable, for they are selected from the best families and are, otherwise, women of unquestionable repute. The empress is the only one who may legitimately bear the name of wife and share his honors. In 1870 the emperor and empress appeared in public together, though they rode in separate carriages ; that of the empress being some distance behind that of the emperor.

In 1890, so fast had public opinion kept pace with

misery they endured in the unaccustomed garments. When I think of the struggles they must have had with the French corset and high-heeled slippers, these women who had worn only loose flowing garments and sandals all their lives previously, I feel that a martyr's crown would be an altogether inadequate compensation for their torment. The majority of the women of the court did not adopt European garments willingly : they were compelled to do so by a proclamation from the empress, who declared that the change in the life and habits of the people, particularly that from the sitting and kneeling etiquette of the Orient to the standing ceremonies of the Occident, required this change in the fashions of women's dress as well as that of men. In a way she was right, for it is said a Japanese man in European dress will treat a Japanese woman clothed in the same fashion with far more respect than he will one clad in the flowing kimono. The sacredness of the royal person hindered the change in dress for the empress for some time, we are told, for no ignoble dressmaker was allowed to touch her. Countess Ito, one of the handsomest and most accomplished women at court, came to the rescue and had

them to separate and fall. The bricks are mortared one against the other, a certain number being placed each way from the girder with the slant toward the center. They are then made secure by means of a center wedge or hollow brick key. Each brick is perforated with a number of square holes which run through lengthwise. The bricks are about 12 inches in length and range from 3×6 inches up to 6×12 inches in width and height, and about ⅝ of an inch in thickness.

In the manufacture, the disintegrator consists of two revolving iron rollers, between which the clay is passed. The rollers are of different diameters, the largest being 42 inches and the other 18 inches. They revolve toward each other, one traveling at the rate of 100 and the other about 50 revolutions per minute. Attached to the small roller are 10 steel strips or teeth, ½ inch in height and about 8 inches apart. The attendants shovel the rough clay into the hopper of the machine, the rollers cutting and mashing it up as it passes between them. For every —— of clay about 8 scoops of ground burnt fire brick and soft coal ashes is added, which gives firmness and body to the mate-

HOLLOW BRICK.

DISINTEGRATOR.

PUGGING CLAY.

BRICK PRESS.

A DIE

INTERIOR OF PRESS.

GRINDING BRICK.
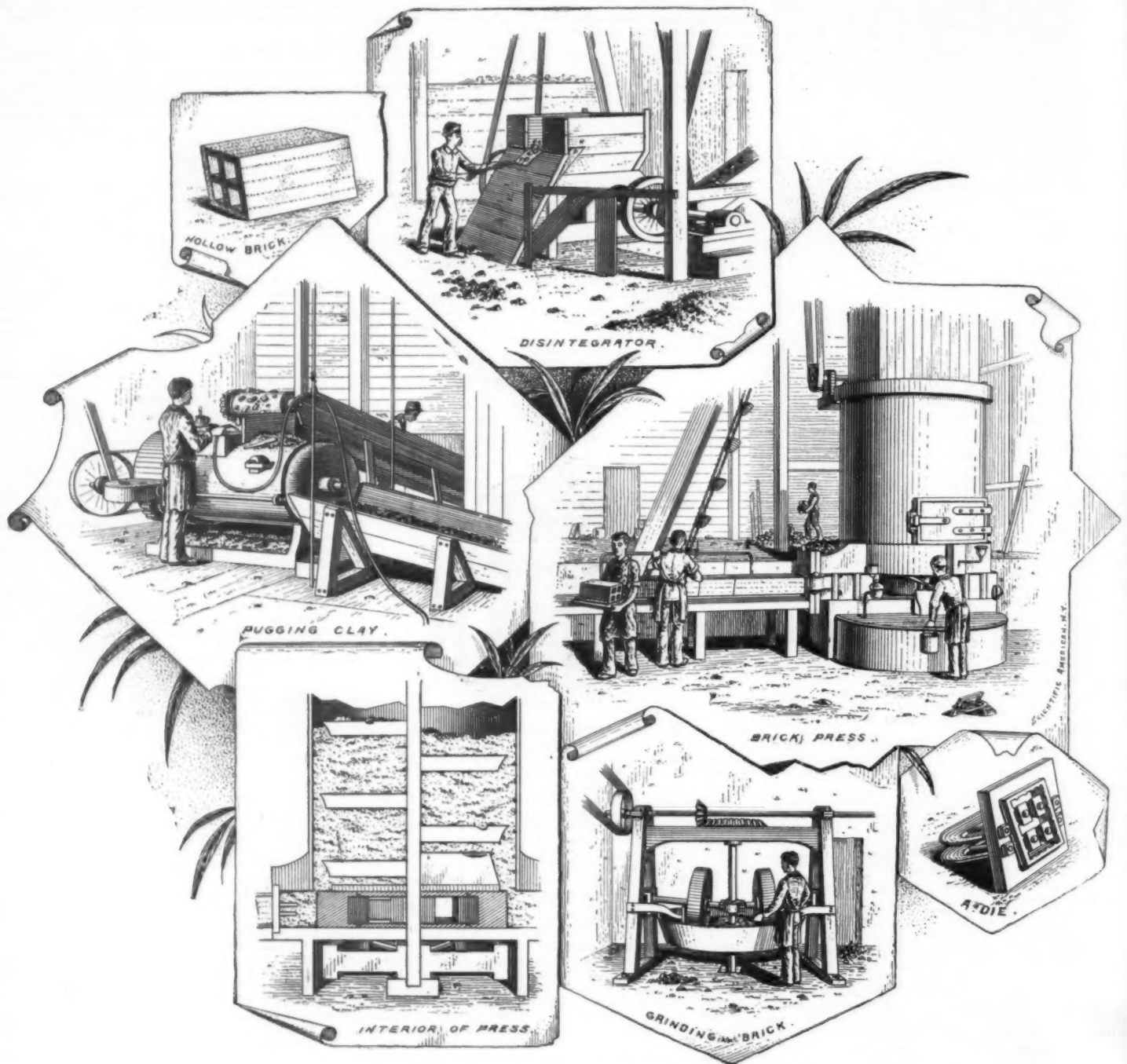
THE HOLLOW BRICK INDUSTRY.

the civilized world, the emperor and empress appeared together in the same carriage, and gravely bowed in acknowledgment of the cheers of foreigners and salutations of their own subjects. In spite of the fact that the Japanese have become accustomed to the sight of the Mikado's face and realize that they will live on in spite of having looked upon it, his name is still supreme and his person as sacred as ever. His prestige has never been weakened by the advances of the nation in the way of democratic development. The priests tell the people they need not weary their gods with many personal petitions—that the Mikado prays daily for his people, and that his prayers are more likely to be answered than theirs—and they still believe it.

Many amusing tales are told of the time when the court was ordered to appear in European garments. Things were put on upside down or wrong side out, and in several cases the biblical declaration that "the last shall be first and the first last" was verified literally. Those were hard days for the poor creatures, but with a stoicism born of centuries of calmness and placidity, they made no outward or visible sign of the

the garments of the empress fitted to her until patterns could be made.

The inner life of the palace is to outsiders a sealed book. We read that the ladies have a large space set apart for them—the wife and each concubine having five or six rooms. Each has also female attendants of a certain rank to wait upon her. These again have their servants, and these also those who wait upon them ; so that they form, as it were, a community of several families.—Pall Mall Magazine.

THE HOLLOW BRICK INDUSTRY.

THE clay from which hollow bricks are principally made comes from the beds at South River, N. J. The material is shipped on canal boats to the manufactory, near New York City, where it is passed through a process of disintegrating and pugging ; the clay then being passed into a press and forced through dies which form the brick into the proper shape and size. The bricks are formed in such a manner as to make an arch when they are placed in position between the iron girders of a building, rendering it impossible for

rial. After passing through the rollers, which forms the clay into scales, it drops down and is carried off by means of a rubber belt to the pugging machine. About 150 tons of clay is disintegrated daily. The fire brick clay, which is added to the common clay, is ground in a circular revolving iron pan about 6 feet in diameter and about 1 foot in depth. The material is ground up by means of two circular iron wheels 36 inches in diameter and about 6 inches in thickness. The revolving of the pan, which travels at the rate of about 50 revolutions per minute, causes the wheels to move over the material, grinding and crushing it up into the right consistency. The wheels weigh about 400 pounds each, and grind about 10 tons of fire brick and soft coal ashes per day. The rubber belt which carries the scales of clay to the pug mill is about 20 inches in width and travels about 40 feet per minute. The clay drops off the belt into the mill, which grinds and mixes up the material again, preparing it for the press. The pug mill is circular in shape, and is about 6 feet in length and about 3 feet in diameter.

The clay is pugged by means of a number of 8 inch curved knives connected to a shaft running through

the center of the cylinder. As the shaft and knives revolve, the clay which is mixed with water is forced forward and squeezed out at the head of the cylinder into an inclined trough. The clay is then forced slowly along at the rate of 4 feet per minute and drops down into the brick press. The cylinder of the brick press is about 4 feet in diameter. At the bottom on each side is an opening about 18×24 inches, through which, by means of 8 curved knives attached to the perpendicular shaft running down through the center, the clay is forced into a square box-like structure, the outer end of which contains the dies through which the material is forced which forms the brick. The clay is forced forward in this box by means of a ram which is driven forward by what is called a pusher, connected to the central shaft of the press. This pusher is semicircular in shape, one end projecting further from the shaft than the other. As the shaft revolves, the short end of the pusher begins forcing the ram ahead, which in turn presses the clay out through the die in the form of a brick. The press maks four pushes per minute, each push pressing out two feet of clay. The bricks are cut off by the attendant passing a number of wires fastened to a frame 12 inches apart through the material. The bricks are then placed upon an elevator and taken to the drying room, where they are placed on their ends and left to dry for 36 hours. After drying they are placed into down-draught kilns and burned for 46 hours at a white heat. These kilns are 15 feet in height, 12 feet in width and 18 feet in depth and hold about 45,000 brick. The kilns are then allowed to cool which takes about 36 hours. As soon as they can be handled they are taken out and packed away for the market. The bricks shrink during the burning operation about one inch. The sketches were taken from the plant of G. W. Rader & Co., New York, who turn out with 40 hands about 6,000 hollow brick per day.

THE WAR KITE.

EXPERIMENTS have been carried on for some time

An older form of military kite.

Experimenting with Lieutenant Baden-Powell's apparatus.
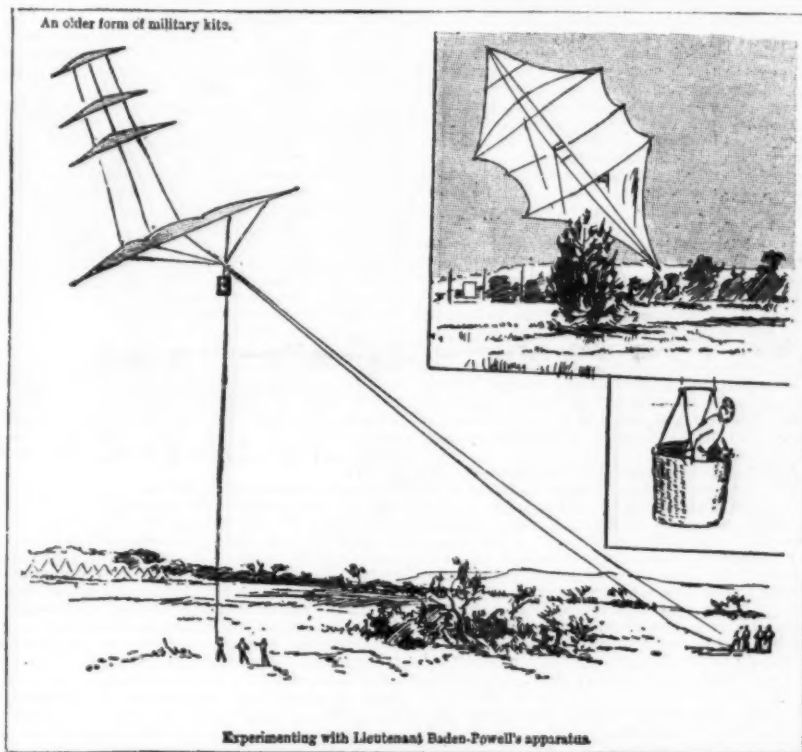
THE KITE IN WARFARE.

past at Pirbright with a new aerial apparatus to be used in place of the captive balloon for military purposes. It is the invention of Lieutenant Baden-Powell, of the Scots Guards, and consists chiefly of a huge kite, containing some 500 square feet of canvas, which is assisted and steadied by other smaller kites. Not only has it been found, writes a military correspondent, that this apparatus can lift a man in moderate breezes, but it has lately been proved capable of doing so in a dead calm, the ropes being drawn along by men or by horses.—London Daily Graphic.

ELECTRICITY DIRECTLY FROM COAL.*
By ALFRED H. BUCHERER.

THE endeavors of scientists and inventors to convert directly the potential energy of coal into electrical energy have received a fresh incentive from the interesting experiments of Dr. Borchers. So alluring are the rewards that follow the solution of this problem that men known for their conservative attitude in similar questions have hailed with extravagant expressions of delight the seeming results of the German electro-metallurgist. It is true the latter deserves high credit for testing his ingenious idea; yet from his own account of the facts brought out in his experiments, I feel sure that as yet his endeavors have been fruitless. Such failure, it is only just to note, could not have been foreseen from the standpoint of our present knowledge of electro-chemistry. In the extensive discussion of Dr. Borchers' work, which appeared in various technical and scientific journals, one point has been altogether ignored, and this point is of such essential importance in the problem of the conversion

of the potential energy of coal into electric energy that it deserves to be fully elucidated. This point is the relation of chemical to electrical energy. Dr. Borchers erroneously supposed that it would be possible to obtain an amount of electrical energy from the reaction $2CO + O_2 = 2CO_2$ that would be equal to the heat of formation of as much of the quantity of the reacting substances as take part in the transformation. Since v. Helmholtz has shown that such a view does conflict with facts, it is no longer legitimate to assume its correctness, still less to base upon it efficient calculations, as was done by Dr. Borchers and Ostwald (see Zeitschrift f. Phys. Chem., 1894, p. 521).

The maximum amount of work which we can derive from a chemical reaction is a definite quantity, and is independent of the kind of energy into which it is transformed. Suppose we have an unpolarizable cell and make the external resistance extremely large as compared with the internal resistance; then, if the quantity m of electricity has passed through the circuit, a proportional amount of chemical action has occurred, and the heat developed in the external circuit is equal to the electrical energy obtained. On examination we will find now that although the internal resistance was vanishingly small compared with the external resistance, yet heat has been evolved or absorbed in the interior of the cell, and it follows from the law of the conservation of energy that the heat of reaction Q is equal to the electrical energy E, minus the heat, q, absorbed in the cell.

$$(1) \qquad \begin{aligned} E - q &= Q \\ E &= Q + q \end{aligned}$$

q can have a positive value or a negative value according to whether heat was absorbed or evolved in the cell. If we consider one electro-chemical equivalent involved in the transformation and measure Q and q in electrical units, then $E = Q + q$ were E measures the E.M.F. in volts. V. Helmholtz investigated the relation which q has to E by applying the second law of thermodynamics. The following reasoning is similar: We know that the mechanical energy of a perfect engine working between the temperature limits $T + dT$ and T is

$$d W = q \frac{d T}{T}$$

$$(2) \qquad q = T \frac{d W}{d T}$$

Now, since the second law of thermodynamics holds for the transformation of heat energy into any other form of energy, it must be true for the transformations occurring in a galvanic cell. Now, as mentioned above, the E.M.F. of a cell measures the energy, if we consider the amount of transformation effected by one electro-chemical equivalent, i. e., the work done by the passage of one coulomb. We can, therefore, substitute d E for d W and we have by substituting d E in (2)

$$(3) \qquad q = T \frac{d E}{d T}$$

and, therefore,

$$(4) \qquad E = Q + T \frac{d E}{d T}$$

$$\frac{d E}{d T}$$

is the temperature coefficient, and it follows that if the E.M.F. of a cell increases with temperature

$$T \frac{d E}{d T}$$

is positive, and the E.M.F. is larger than the value

calculated from the heat of transformation, and heat is absorbed in the cell; whereas, if the E.M.F decreases with temperature, the E.M.F. is smaller than the value Q expressed in electrical units. Heat is evolved in the interior of the cell. Now, in some primary cells the temperature coefficient is so small that it can be practically neglected; in others it is so great that the E.M.F. as calculated from the heat of formation will give a decidedly wrong value. With a reaction that is so different from those utilized in ordinary cells, and concerning which we know so little as the one utilized by Dr. Borchers, it is not legitimate to form any conclusions as to the E.M.F. obtainable.

The question now presents itself, What is then the maximum E.M.F. we can expect to gain from the combination of carbon monoxide with oxygen? Is there any reversible transformation, no matter into what kind of energy, about which we do know something? There is such an ideal process, and I will show the reasoning by which we can arrive at the desired value. The reasoning is based on the principle of the dynamical equilibrium of chemical systems, which principle is nothing else than a disguised form of the second law of thermodynamics. When carbon monoxide combines with oxygen, not all of it is thus oxidized, and at a definite temperature and pressure the composition of the resultant mixture of gases, consisting of CO_2, CO and O_2, is definite. Deville found experimentally that at a temperature of $3,000°$ Celsius forty per cent. of the carbonic acid is dissociated at atmospheric pressure. I have calculated from this fact that at a temperature of $0°$ Celsius and atmospheric pressure, the fraction of dissociated CO_2 is

$$\frac{1 \cdot 58}{10^{34 \cdot 65}}$$

If we conduct the process of combination of CO and O in such a manner that the maximum amount is being obtained, and take care that the temperature does not change, then this work depends on the initial and final condition of the gases. Now, let us suppose 2 gramme molecules of carbon monoxide, i. e., 56 grammes at atmospheric pressure, react on 1 gramme molecule, i. e., 32 grammes of oxygen, also at atmospheric pressure, in a reversible manner, and that the carbonic acid formed is likewise brought to atmospheric pressure. Then, evidently, since, as we have seen, the dissociation of the carbonic acid is extremely small, the partial pressure of the carbon monoxide in the product of the reaction must also be very small, and the carbon monoxide, while performing work, has been brought from the atmospheric pressure to an exceedingly small pressure. Now, if the partial pressure of the CO be p_1, then the work done is

$$W = 2 RT \log_e \frac{1}{p_1}$$

where R is the gas constant referring to 1 gramme molecule of gas and is equal to $1 \cdot 98$ calories. The oxygen is similarly brought from the atmospheric pressure to a partial pressure, which is one-half of the partial pressure of the carbonic oxide; for the gases being present in the ratios in which they react on each other, two volumes of CO are present to one molecule of oxygen, and the pressure of the carbonic oxide is twice that of the oxygen. Hence, the work performed by the oxygen is

$$RT \log_e \frac{2}{p_1}$$

Since the carbonic acid in the reaction mixture is practically under atmospheric pressure, no work appreciably is done upon it, and the total energy obtained by the reversible combination of the two molecules of CO with 1 gramme molecule of oxygen is

$$W = 2 RT \log_e \frac{1}{p_1} + RT \log_e \frac{2}{p_1}$$

$$(5) \qquad W = RT \log_e \frac{2}{p_1^3}$$

Since now the fraction of the CO_2 that is dissociated at $0°$ Celsius is

$$\frac{1 \cdot 58}{10^{34 \cdot 65}}$$

it follows that the partial pressure, p, of the CO is

$$\frac{1 \cdot 58}{10^{34 \cdot 65}}$$

atmospheres. Substituting this value in equation (5) we have

$$W = RT \log_e \frac{10^{104 \cdot 65}}{2}$$

This energy refers to the chemical combination of 2 gramme molecules, and is expressed in calories. To obtain the energy for the combination of one electro-chemical equivalent, expressed in electrical units, we divide by 4×23039, and we have

$$E = \frac{1 \cdot 98 \times 273}{4 \times 23039} \log_e \frac{10^{104 \cdot 65}}{2} \text{ volts.}$$

$$E = 1 \cdot 41 \text{ volts.}$$

This is the value for $0°$ Celsius. The heat of formation of carbonic acid is 68000, and the E.M.F. calculated from this is $1 \cdot 476$. Therefore, by the equation of v. Helmholtz,

$$1 \cdot 41 = 1 \cdot 476 + 273 \frac{d E}{d T}$$

$$\frac{d E}{d T} = - \frac{0 \cdot 066}{273}$$

The E.M.F., therefore, decreases by

$$\frac{0 \cdot 066}{273}$$

volts, with every increase of temperature by 1°. At

the standard temperature, 18° Celsius, the E. M. F. is, therefore,

$$1.476 - 291 \frac{0.066}{273}$$

$$1.476 - 0.07 = 1.406$$

We thus see that the E. M. F. is somewhat smaller than assumed by Dr. Borchers. The greatest E.M.F. obtained by Dr. Borchers was 0·5 volt. The conclusion which he now draws from this result is that he has already succeeded in obtaining about thirty per cent. of the energy of the coal, whereas, the steam engine converted much less. This is another non-admissible conclusion. For, in an unpolarizable, i. e., reversible, cell, the maximum E.M.F. is a definite value, and if another value is experimentally observed which very appreciably differs from it, then, barring secondary actions, the reaction which is expected to furnish the electric energy does not occur. To say that secondary actions depress the theoretical E.M.F. is not logical in this case, for, evidently, this secondary E.M.F. would have to be about twice as great as the observed E M F., and, therefore, could not be called secondary.

The action that took place in Dr. Borchers' apparatus is most probably one that can be found among those which were investigated and published by Mr. Mond (see London Electrician, January 11, and Digest Electrical World, New York, February 2). It would lead too far to discuss in detail the work of Mond, and to single out the particular action to which the E. M. F. of the apparatus of Dr. Borchers was due.

For reasons which were well stated by the latter, it is more expedient and apparently easier to utilize the combination of carbon monoxide with oxygen for the generation of electric energy instead of that of carbon with oxygen. The work done by Dr. Borchers, though not crowned with success as yet, is, nevertheless, of high value on account of its instructiveness. It indicates in its general features the path that has to be followed for accomplishing a most important industrial task, the fulfillment of which we hope this century will yet witness.

HOW TO RIDE IN A RAILWAY TRAIN.

By CHESTER N. FARR, Jr.

WE offer no excuse for the writing of this article. Had the intricacies of railroad accident law been developed to their present extent at the time Poor Richard wrote his almanac, he would have infallibly produced a chapter somewhat similar to this of ours. We intend ultimately to publish it as a "Handbuch" for tourists, so that it may become a familiar and indispensable accompaniment of a traveler's kit. The world has long stood in need of an article of this character, and it is with a feeling of pardonable pride that we offer this one to the world aforesaid.

The advantages of the article are obvious. You, for example, reader, meet with what is popularly called an accident on a railroad train. You are injured, your business falls in arrears, your physician becomes a too frequent visitor, you are boiling with indignation against the company. You sue for damages and indulge the pleasing expectancy of just retribution. But, my dear friend, you have failed to recognize that there is, in the eye of the law, a monstrosity known as "the ordinary man, exercising reasonable care, under the circumstances." You have failed to conduct yourself with that prudent nicety which this gentleman would have exercised under like conditions. You are nonsuited or a verdict is directed against you. Had you but read this article, you might have recovered substantial damages to pay for your business neglected, your body permanently injured, and your physician's bills. It is the high function of this essay to inform you as to what you should do when you ride on a railway train.

Imprimus: Let us see how one should board a train. But, eh? Is it possible that you are a sneering reader? And what is that you say? Any ass can do that? Now, faith, this is a display of the most cardinal lack of information on your part. Crassa ignorantia, we may call it, and "ignorance of the law," according to a maxim somewhat well thumbed in legal fingers and a trifle out at the elbows, "excuseth no one." For, in sooth, there is no more complicated problem in all human action than this same conduct of one's self in boarding a railroad train, unless, perchance, it be alighting from the same.

This is such a progressive country that loafing habits of any description whatsoever are intolerable. Most individuals are presumed to know how to conduct themselves in a railway station within the limits of becoming decency—but in the eyes of the law—in its eyes, beware reader, lest you loiter in the ticket office to speak to a friend after having purchased your ticket: R.R. Co. v. Fox, 6 S. W. Rep. 569. For you must pass quickly to the platform, keeping a sharp lookout for mail bag piles, and so on, which the care of the company may have placed in your path: Ayres v. R.R. Co., 77 Hun. 414. Perhaps these may be negligently placed, but that is not for you to determine. Having reached a small station at an unseasonable night hour to wait for a train, take good care to seek a spot of safety and remain there: Grimes v. R.R. Co., 36 Fed. Rep. 72 Are you cold and need exercise? The court has been pleased to permit this, but be most cautious in its conduct; the passage between Scylla and Charybdis or the Valley of the Shadow of Death is not more difficult. Call loudly for "light," even though you know the station agent is slumbering peacefully several parasangs in the distance: Wood v. R.R. Co., 13 So. Rep. 555. For once, having called so loudly, you may walk gracefully into any obstruction you choose in the darkness, and recover handsome damages for injuries consequent thereon.

Take especial pains to regulate your conduct with propriety as another train draws into the station. Do not stand on the planking between the tracks, no matter how alluringly convenient it may seem: McGeehan v. R.R. Co., 149 Pa. 188. When standing on a narrow space in front of a raised baggage platform remain perfectly calm and flat as a train moves rapidly by you. It usually gives you a margin of at least six inches. You may think the margin a minus quantity,

but should you attempt to gain any special "coigne of vantage" and be struck while so doing, only the railroad company will forgive you: Matthews v. R.R. Co., 148 Pa. 491.

The railroad company is not responsible for the subsequent career of mutilated bodies thrown indiscriminately around by the action of the train. Practice in rapid dodging is considered an exercise of reasonable care, and when Mr. Wood, a respected citizen of Philadelphia, was struck by a flying corpse while standing on a station platform, the courts declined to consider his case: Wood v. Pa. R.R. Co., 4 Dist. Rep. 119.

On entering a car rush instantly for a seat; do not stand leisurely looking to see which pretty girl you are going to seat yourself beside. This is not a time for the inspection of female loveliness. Take a seat, p. d. q. (N. B. This is not verbatim from the opinion): De Soucey v. R.R. Co., 15 N. Y., S. 108. The courts are graciously pleased to permit a passenger to sit next the stove on a cold day. If you are thrown into it by a sudden jerk of the train, as Mr. Stewart, of Texas, was, you may recover. This is gratifying: R.R. Co. v. Stewart, 1 Tex. Civ. App.

Pointing out scenery to an admiring friend while seated at a car window or endeavoring to pull down telegraph poles or station posts with your hand as they are passed, is not an exercise of due care: Quinn v. R.R. Co., 7 S. E. Rep. 614. The platform of a car is not the proper place for a passenger: Toney v. R.R. Co., 18 N. E. Rep. 213. The fact that you are going to a football match or prize fight and could not get in the car, even were you as thin as tissue paper, affords no excuse in the omniscience of the law: Worthington v. R.R. Co., 64 Vt. 107; and if, being a modest man, you have just offered your seat to a lady, and desire to conceal your blushes on the back platform, we are afraid that your only alternative is the toilet room. You may enjoy the society of the baggage agent, but it is negligence, per se, to talk to him: R.R. Co. v. Langdon, 92 Pa. 21. Nothing, not even a cinder in your eye which only the baggage agent can extract, justifies your presence in the baggage car.

Riding on the cupola of a caboose car, though an exalted attitude, is not one of due care. Mr. Tuley, of Missouri, thought otherwise. He did not recover: Tuley v. R.R. Co., 41 Mo. App. 432. Similarly a position on the coping of an engine tender or the sheet iron covering of the steps of an elevated railroad car, while they may afford unsurpassed opportunities for viewing the scenery, are held to be objectionable actions by the courts: Carroll v. R.R. Co., 17 S. W. Rep. 889; R.R. Co. v. Riley, 40 Ill. App. 416.

Do not, in your innocence, seat yourself on the arm of a car seat to converse with a friend. The railroad company is not responsible for your safety under such conditions. While this post offers excellent advantages for whispering soft nothings into the ears of Venus, the railroad company is not legally expected to afford facilities for love making, and such action may be regarded as negligence, per se: Wallace v. R.R. Co., 4 S. E. Rep. 503. As a matter of safety, it is probably better to rush swiftly to a seat, and plank yourself solidly upon it, for though courts have passed no opinion upon one who rides on the truck of a passenger car or the top of a locomotive smoke stack, certain well informed individuals have shrewdly inferred that they might regard proceedings of this nature in the light of mild contributory negligence.

The law has a strong opposition to idle curiosity, and if the train by chance should stop, be thoroughly convinced in your own mind that the point of stoppage is a station ere you alight. A water tank or switch house will not suffice: Wandell v. Corbin, 1 N. Y. S. 795. Having once securely seated yourself, take good care if the car be insufficiently heated to complain loudly to the officials, for having done this you may resume your seat and welcome sore throat, malaria, bronchitis, pneumonia and consumption, with the pleasing assurance that the railroad company will be required to pay your doctor's bill and compensate you for physical suffering besides: Hastings v. R.R. Co., 33 Fed. Rep. 858.

It is a charming sight to see a man step airily off a train which draws into a station, and rush to the fond embrace of a loving wife or expectant sweetheart, and as he does this no one imagines that he is performing a feat of the most complicated description, in comparison with which the problem of three bodies sinks into puerile insignificance! "Railroads are run for the public convenience!" This was a rather injudicious statement made by a Massachusetts judge. Fortunately it was obiter, otherwise it might have revolutionized the law. Perhaps he meant to say: "The public are run for the convenience of railroads."

There is a certain intricate action performed by railroad officials, known to the omniscience of the law as an "invitation to alight." Such invitation we may hint to the uninitiated is not couched in terms such as "The Northern Pacific Railroad Company presents its compliments to J. S. and will be pleased to dispense with the pleasure of his company at Walla Walla station." No, indeed. An individual pokes his head in at the door and calls out: "Xyzhirtlmxpq." It then becomes your duty to conduct yourself in the following manner: Think carefully of the important proposition of law, to wit: That passengers are expected to know that trains stop at places other than stations. Some have been known to stop temporarily in a cut, but under such circumstances it is negligence per se for you to alight, even though sunk in absence of mind, and endeavor to scale the embankment: Smith v. R.R. Co., 88 Ala. 538. You must realize the fact that two announcements are sometimes made of a station, one before and one upon arrival. If in doubt upon this dubious point, it is your duty to inform yourself of your whereabouts: Minock v. R.R. Co., 56 N. W. Rep. 780. Having satisfactorily turned over these points in your mind, do not fail, under all circumstances, to be thoroughly convinced that the individual, who so hastily thrust his head in at the door, called out an indistinguishable name, and as hastily withdrew his countenance from your view, do not fail, we repeat, to convince yourself, that this individual is an officer of the road, and one in authority. This may, to be sure, necessitate your walking through several sections of the train, and making proper inquiries on the route, but if it should so happen that the voice in question emanated

from a throat less august than that of a railroad official, it does not constitute, in the eye of the law, an invitation, and you may be negligent in alighting: R.R. Co. v. Farrell, 31 Ind. 408.

The mental process necessitated by these acts is a trifle involved, but the company, so runs the law, must perforce permit every passenger a reasonable length of time in which to alight. But what is a reasonable length of time do not attempt to determine. That is the province of the jury.

We will suppose your intellect acts very rapidly—that you have inspected the surroundings—that you have thoroughly grasped the legal principles which we have presented you—that you have pursued the person who called the station, through the train, and have discovered him to be the conductor; and now finally, you reach the platform, panting with your physical and mental exertions, and just as you are stepping off, in full view of an official, the train starts to move.

Ah! happy, thrice happy man, are you hurt under these conditions? For, observes the sapient law, it is negligence on the company's part to start the train when one is plainly perceived in the act of alighting, even though such person may have waited an unreasonable length of time. "For a human being," said a Texas judge, in a temporary ebullition of Christian charity, "does not forfeit the right to live on account of being negligent." This is refreshing: R.R. Co. v. Weisen, 65 Tex. 443.

Having fully satisfied yourself that the invitation is one meeting with all the requirements of the law, it is your duty to exercise ordinary care in alighting: R.R. Co. v. Williams, 7 S. W. Rep. 88. Perhaps you are under the impression that you know what ordinary care is. Here we beg leave to disabuse your mind. The train is expected to stop at a station a reasonable length of time, and conversely you are expected to occupy only a reasonable length of time in leaving it. Rush rapidly to the platform, and plunge down every step until you reach the last, then pause, for you have much to consider at this particular point. Should you alight while the train is moving, even though it might not have stopped a reasonable length of time, you are guilty of negligence: Cousins v. R.R. Co., 56 N. W. Rep. 14. If you are standing on the platform while the train is slowly moving in the station, and a sudden jerk precipitates you to the ground, you are negligent: Secor v. R.R. Co., 10 Fed. Rep. 15.

In general, if the train be moving, be it ever so little, 'tis well not to alight. Do you see the transaction of important business slipping from your grasp, do you see home, friends, family, vanishing in the distance, do you realize an empty purse, and the next stop, midnight in a strange city, 100 miles away, under no circumstances may you so far forget yourself as to jump: R.R. Co. v. Bangs, 47 Mich. 470; Johnson v. R.R. Co., 70 Penn. 357. You may have agreed with the conductor to stop at your particular place, and not impossibly you may have clinched the bargain by a slight pecuniary consideration, but that is no excuse; better the loss of money, friends, fortune, than the charge of negligence, per se: Barnett v. R.R. Co., 87 Ga. 766. You may imagine it an exceptional case when the train is derailed and is bumping over the ties, and that you might be permitted to jump under such terrifying conditions. Perhaps it is best to err on the safe side. This may or may not be negligence: R.R. v. Rohrman, 13 W. N. C. 258. You had better take affairs easily, sit down, light a cigar. This is not negligence.

You are standing on the car steps, the train is moving slowly out, and has not stopped. The conductor, addressing you in that polite, engaging manner that distinguishes American railroad officials, orders you to jump. Now here is a difficult problem. If the attempt be manifestly dangerous, you must resist the polished insinuations of the conductor and remain on the car. Since the determination of what is "manifestly dangerous" necessitates the injecting of yourself into the minds of a modern jury, an intellectual feat before which Sir Isaac Newton might well quail, possibly it were better you swallowed the large lump in your throat, and, banishing the pleasures of a cozy fire, a fascinating book or a steaming supper from your recollection, returned to the car: Riebel v. R.R Co., 17 N. E. Rep. 107. If, however, you are pulled violently to the ground by a gentlemanly official, while standing upon the steps of a slowly moving train, you are privileged to recover damages: R.R. Co. v. Wood, 14 N. E. Rep. 572. N. B.—We are charmed to record this oasis in a desert of negligence.

Suppose the train has stopped. You reach the last step of the platform and prepare to alight. The step is too high from the ground, then call loudly for assistance, though perhaps you may be confronted by another rule of law which says that the conductor is not required to assist a passenger to alight: Raben v. R.R. Co., 35 N. W. Rep. 645; but this only applies to ordinary circumstances. Never attempt to determine what ordinary circumstances are, but having bellowed persistently for assistance, return quietly to the car and resume your seat with a patient resignation that affords a strong contrast to the conduct of Mrs. McDermott, of Wisconsin, who insisted upon jumping, despite the height, and was seriously injured thereby: McDermott v. R.R. Co., 52 N. W. Rep. 85. And, finally, one thing more, notice critically where you are about to step. A certain lady of Pennsylvania stepped upon the bung of a beer barrel which was lying upon the station platform as she left the train, but she never got a cent of damages, for the court thought this was too ordinary an obstruction: Bernhardt v. R.R. Co., 159 Pa. 360. Just what would be such an extraordinary obstruction as to make the railroad company liable we are not prepared to say. Possibly, a package of nitroglycerine or a pot of boiling pitch.

But you have avoided bungs, you have not ridden on the coping of the engine tender (see supra), you have not shillyshallyed before mounting the train (see supra). You are home, you are safe.

Ah, little does Cecilia, Camilla, Evelina or Flabella think, as she clasps her loving Mortimer in her arms, of the way beset with dangers through which he has passed. Hug tighter, Cecilia, and though it be but a short ten miles of iron road that separates Mortimer from his office, think twice ere you determine to remain in the suburbs another year.

We have had serious hesitancy in sending the above

to press. We are willing to confess that since reading up the subject of negligence on railroads our own existence has not been a supremely happy one. There is a consciousnes of self, a feeling of hopeless ignorance in a vast sea of essential knowledge that oppresses the spirit. Perhaps it is wrong to introduce like feelings into minds now blissfully unconscious of error; perhaps—but the point is too knotty. We will at least save men from riding on engine cowcatchers or dancing the bolero on top of a Pullman palace car. Doubtless we have not labored in vain.—The American Law Register and Review.

UNCLE SAM SEEN BY FRIENDLY EYES.

In the current number of the North American Review Mr. Michael G. Mulhall, F.S.S., makes a study of those elements of power and wealth in the United States which, as he expresses it, have "enabled a community of wood cutters and farmers to become, in less than one hundred years, the greatest nation in the world."

Mr. Mulhall, a native of Ireland, educated at the Irish College of Rome, has been of high repute for many years as a statistician. His experience in the study of the strength and resources of nations gives value to his present array of facts and figures, and to his emphatic declaration that "if we take a survey of mankind in ancient or modern times, as regards the physical, mechanical, and intellectual force of nations, we find nothing to compare with the United States in this present year of 1895."

The units of power which he employs in his calculations are themselves interesting. The working power of an able bodied male adult, he tells us, is 300 foot tons daily; that of a horse, 3,000; while the standard of steam horse power is 4,000. The foot ton is that amount of power which, if concentrated and applied, could raise a ton to the height of a foot. Taking this basis, Mr. Mulhall finds the working power of the United States to be approximately as follows at various dates:

Year.	Millions of foot tons daily.				Foot tons daily per inhab.
	Hand.	Horse.	Steam.	Total.	
1820	753	3,300	240	4,293	446
1840	1,406	12,900	3,040	17,346	1,020
1860	2,805	22,200	14,000	39,005	1,240
1880	4,450	36,600	36,340	77,390	1,545
1895	6,406	55,200	67,700	129,306	1,940

In this reckoning the working power per inhabitant is seen almost to have doubled since 1840, while the entire effective force of the American people is more than three times what it was in 1860. The most rapid growth, of course, is in steam power. The horse power of steam is nearly twice as great this year as it was fifteen years ago, taking together locomotive engines, steamboats, and the fixed power of mines and factories, and nearly five times as great as that of 1860. To illustrate the energy of the United States he compares it with that of other nations:

	Millions of foot tons daily.				Foot tons per inhab.
	Hand.	Horse.	Steam.	Total.	
U. S.	6,406	55,200	67,700	129,306	1,940
Gr. Brit.	3,210	6,100	46,800	56,110	1,470
Germany	4,280	11,500	29,800	45,580	902
France	3,380	9,600	21,600	34,580	910
Austria	3,410	9,900	9,200	22,510	560
Italy	2,570	4,020	4,800	11,390	380
Spain	1,540	5,500	3,600	10,640	590

"Here we see that the United States possess almost as much energy as Great Britain, Germany, and France collectively, and that the ratio falling to each American is more than what two Frenchmen or Germans have at their disposal. Moreover, the military armaments which keep in forced idleness 4,000,000 men in Europe are happily unknown in the United States. It is not merely that European nations are deprived of the labor, skill, and exertions of 4,000,000 men in the prime of life, they have also to set apart 1,000,000 workers of the agricultural and industrial classes to feed and clothe the standing armies and defray the cost of artillery, war vessels, etc. Thus the average of productive energy in France, Germany, England, etc., is much less than appears in the above statement.

Again, in the labor-saving appliances of the United States he sees the perfecting of machinery; the reaping machine for example, commonly used in the Western States, "will cut and bind grain at the rate of forty-five minutes per acre." An ordinary farm hand in the United States, says Mr. Mulhall, thanks to these mechanical appliances, raises as much grain as three hands do in England, four in France, five in Germany, and six in Austria. Reducing all farm products to a grain standard by supposing ten pounds of meat or two gallons of wine to be equal to a bushel, he finds the number of bushels of grain per hand raised in the United States to be 475; in the United Kingdom, 228; in France, 188; in Germany, 118; in Italy, 115; in Austria, 97. Yet again he quotes Mr. Atkinson as showing that in America the labor of one man in 300 days in the year is equivalent to the production of 4,500 bushels of wheat, while that of three other men represents the cutting, thrashing, milling, and transporting to market. Thus four men carry to the baker's flour for a thousand persons, at twelve ounces of bread daily for a year. "In other words, one man can feed 250, whereas in Europe one man feeds only thirty persons;" and little improvement in Europe can be expected, because so many people there consider that labor-saving appliances are an evil, and that the more persons there are employed in doing any given work, the better.

Passing to other matters, Mr. Mulhall declares that "the intellectual power of the Great Republic is in harmony with the industrial and mechanical." The census of 1890 showed that 87 per cent. of the total population over ten years of age could read and write, and he asserts that "in the history of the human race no nation ever before possessed 41,000,000 instructed citizens." The annual school expenditure in the United States is $156,000,000, or $2.40 per inhabitant, against $48,000,000 and $1.30 in Great Britain; $31,000,000 and 0.80 in France; $26,000,000 and 0.50 in Germany; $12,000,000 and 0.30 in Austria; and $7,000,000 and 0.25 in Italy. Again, the letters per inhabitant carried yearly, according to the post office returns, are 110 for the United States, 74 for Switzerland, 60 for Great

Britain, 53 for Germany, 49 for Belgium, 40 for Holland, 39 for France, 24 for Austria, and 16 for Italy.

The growth of wealth in this country seems to Mr. Mulhall still more marvelous than the growth of physical power. He finds the wealth of 1820 to be $1,960,000,000, that of 1860 to be $16,160,000,000 and that of 1890 to be $65,037,000,000. And this last computation omits public lands. The number of dollars per inhabitant was $205 in 1820, $514 in 1860, and $1,039 in 1890. Still, there are three countries in Europe that surpass us in this latter particular, namely Great Britain with $1,260 per head, France with $1,130, and Holland with $1,080. They, on the other hand, represent the accumulations of many generations, while ours is a new country.

The distributions of wealth in rural and urban communities and in different parts of the country also furnish Mr. Mulhall with interesting computations. Here, too, are some interesting conclusions, first in regard to railway lines and then in regard to houses.

"The freight charge in 1890 averaged ninety-three cents per ton per hundred miles, which is less than half the charge customary in Europe ($1.90), and this implies a saving in this respect alone of $845,000,000 yearly to the American people, or ten per cent. on the original cost of constructing the lines. Another large item in the increment of wealth is houses, which represent an annual investment of $12 per inhabitant of the whole Union during twenty years ending 1890. The annual average in Great Britain is $5.50, and, as economists recognize the outlay on houses to be a gage of wealth, it appears that the average accumulation in the United States is double what it is in the mother country. In effect, English statisticians estimate the ordinary accumulation in Great Britain at £5, say $24, per head, whereas we have seen that the American average is $41 per head."

The conclusion is that our country is now "by far the greatest productive power in the world;" that the intellectual progress of the nation "is attended to in a more liberal manner than in Europe," and that the accumulation of wealth averages $7,000,000 daily. "These simple facts tell us what a wonderful country has sprung up beyond the Atlantic in a single century, and furnish a scathing commentary on the books written by English travelers only fifty years ago." Englishmen now, according to Mr. Mulhall have more correct views, while "the rest of mankind marks with wonder and admiration the onward march of the Great Republic." There is no doubt, at all events, of the sincere good will which this admirer of America has for us.—N. Y. Sun.

THE FADING OF PIGMENTS.[*]

By Captain W. De W. Abney, C.B., F.R.S.

It is not my intention to-night to enter into the causes of the fading of pigments, whether water color or other. Were I to do so, I should have to keep the meeting considerably longer than either they or myself would consider desirable. I think I must take it for granted that the conclusions Dr. Russell and myself arrived at in 1888 (the date when we made our report to Parliament) have not been controverted or whittled away and may be accepted as correct. I must, however, quote two of the concluding paragraphs: "It may be said that every pigment is permanent when exposed to light 'in vacuo,' and this indicates the direction in which experiment should be made for the preservation of water color drawings;" and "our experiments also show that the rays which produce by far the greatest change in a pigment are the blue and violet components of white light, and that these, for equal illumination, predominate in light from the sky, while they are least in sunlight, and in diffused cloudlight, and are present, in comparatively small proportions, in the artificial lights usually employed in lighting a room or gallery."

At the end of the report we make some reference to glazing the skylight with yellow glass, and point out that it would be inexpedient to do so, as, although the safety of the pigments' colors would be thereby insured, or at all events be made more certain, yet in such a light the hues of the blue pigments would suffer to the eye.

The first method of preserving the color of pictures by placing them in vacuo has been experimented upon by a company, and it would not become me to say what success they have attained in this direction. The method that I have adopted to minimize fading has been in the direction of controlling the kind of light admitted to the pigments. The point from which I started was from the results of the experiments made as to the fading of different pigments under colored glasses. The glasses employed were red, green and blue, which are approximately the three primary colors, and it may be instructive to show you the rays which these three glasses allow to pass. If in the front of the slit of the spectroscope a piece of red glass is placed, we see that the spectrum is deprived of all the green and blue rays, only red, orange and a few yellow rays being transmitted. With the green glass the

red rays are almost altogether absent, as are also the violet, but the green rays are strong, as are the blue green, and there is a fair proportion of yellow and blue rays passing.

Through the blue glass the violet and blue rays pass readily, the green and yellow and red are cut off, though there are two faint bands apparent in the yellow green and in the red. It will be noticed that practically these glasses divide the spectrum into three parts, (1) the violet and blue, (2) the green and yellow and (3) the orange and red.

The following table shows how little action takes place under any glass except the blue, and our statement that the greatest fading in white light is caused by the violet and blue rays is founded on it:

	White.	Blue.	Green.	Red.
Purple madder	Faded to 2	Faded to 1	—	—
Antwerp blue	No experiment	Faded	—	—
Leitches blue	Sl. faded	Sl. faded	Darkened	Darkened
Violet carmine	Faded to 1	Faded to 1	—	—
Paynes gray	Faded to 1	Bluer	Blue	—
Indigo	No experiment	Faded to 1	—	Sl. faded
Prussian blue	No experiment	Sl. faded	—	V. sl. faded
Rose madder (two experiments)	Sl. bleached	Sl. faded	—	—
Brown pink	No experiment	Faded to 3	—	—
Crimson lake	No experiment	Faded	Sl. faded	Sl. faded
Vandyke brown	No experiment	Faded to 1	Sl. faded	—
Vermilion	Darkened	V. sl. darkened	—	—
Carmine	No experiment	Faded to 3	Sl. faded	—
Gamboge	No experiment	Faded to 1	—	—
Indian yellow	No experiment	No change	—	—
Sepia	Became lighter	Became lighter	—	—
Burnt sienna	No change	No change	—	—

Other experiments have shown me that the violet rays are the most active in producing fading, as they are also in producing an ordinary photographic image. If we can eliminate the majority of these rays from white light without appreciably altering the freshness of the colors viewed in such light, we shall practically have prolonged the life of a picture. At first sight that these conditions can obtain may appear problematical; but I trust that you will agree with me shortly, that we can cut off some of these rays without injuring the hue of the color.

Now, I must ask you to take it from me, from a series of experiments made, that ultramarine is that pigment whose dominant color is nearest to the violet end of the spectrum, and when I say dominant color, I mean a color which has approximately the same color as a spectrum color, though it may be mixed with white light to a variable amount.

We can show the dominant color of some pigments. For instance, here is an orange pigment: I can match that in the spectrum by one orange ray. Emerald green I too can match, but we must have a certain amount of white light mixed with it. Pure ultramarine, too, we shall see, has a dominant wave length well below the G Fraunhofer line. It therefore follows that if we illuminate all pigments with a compound light, in which this ultramarine spectrum color is included, they must appear appreciably the same as they do in white light.

I must guard myself, however. Do not let us suppose for one instant that these dominant colors are alone those that are reflected from the pigment. They reflect a good many more. We can show that this is the case. I place a pigment in the patch of monochromatic light from the spectrum, which can be changed at will, and, the more luminous the pigment appears in any particular color, the more of that particular light we know is reflected. Thus we place emerald green in the patch, and we see that it reflects but little red, more yellow, a maximum in green and a very little blue. We also find that vermilion reflects a maximum in the red, very little yellow and practically nothing else. Ultramarine, we find, reflects a very little red, no yellow, a very little green, plenty of blue and some violet. If we cut off the violet from the spectrum and place the ultramarine in it, we shall, however, find the color appreciably the same as it was when the violet was present.

A variety of experiments made with these different pigments tell us that the loss of the violet of the spectrum is practically no loss at all. Even with white light the loss is unnoticeable. If we form a patch of light composed of all the colors except the violet, we shall notice but very little change from the pure white which is alongside of it.

Having established this fact, we are now in a position to go a step further.

In the apparatus I have here at hand I can place three slits in the spectrum, and by means of a convex lens of proper focal length and curvature, I can cause these colors to recombine and form a patch of white light, being an image of the prism. The slits are now in the spectrum, and a patch of pure white light alongside. I alter the width of the slits till they show the patch of the same color as the comparison white. The colors are red, green and blue. Now, the red and the green themselves, when mixed, form a yellow, and this can be demonstrated by covering up the slit through which the blue issues—you will see a yellow patch on the screen; evidently, then, since red and green make yellow, a yellow and a blue will form white light. To prove this further, I place a slit in the yellow and another in the blue, and we have white again formed. As a matter of fact, with any kind of yellow and any kind of blue there is always some blue ray and some yellow ray which will form white light with them respectively by their mixture. But it does not follow that such a white light is a proper one in which to view colored pigments. For instance, in this mixture of blue and yellow of the spectrum I place an orange; you see it appears yellow; or if I place a green in it, it appears whitish, and so on. I might multiply my experiments in this direction, but they would only prove that there must be something beyond a mere match of white light to make it effective as a pigment illuminant.

That "something beyond" is really a continuous spectrum. That is, every ray must be present except the violet rays, which have been shown to be practically useless for giving illumination (I may mention

[*] Read before the Society of Arts, London, May 15, 1895.—From the Journal of the Society.

that the yellow ray has about 200 times the illumination of the strongest violet ray, which we can spare without detriment). Where a portion of the spectrum is altogether absent or deficient those pigments whose dominant colors lie where these deficiencies are to be found must inevitably alter in hue, just as we found to be the case just now. If we can get a yellow and a blue, which together will have such a spectrum when combined together, we shall have accomplished what we want.

Now here is a green-blue glass, such as is used for ordinary ships' lights. When placed in a beam of white ray, a place in the spectrum can be rapidly found where the yellow is such as will form a white light with it, or a yellow glass can be placed in the white light and a blue ray found, which, when mixed with it, forms white light.

You see the mixtures before you, and I fancy will not find much fault with them. If we compare the blue-green spectrum ray which forms the white light with the light coming through the yellow glass, we find that it matches the blue of the glass very closely. Evidently, then, we can mix the light coming through these two together, and they should also form white light. This we can easily test. The blue glass is in one beam of white light and the yellow in the other. By superposing on the same screen these two lights and then reducing them to proper proportions, we see that we have a white light which is a very close match to that of electric light.

Another step further we must go. Is the blue-green glass of that type which cuts off the proper amount of violet light? This we can answer at once by an appeal to the spectrum. We have the spectrum of the electric light on the screen, and place in front of the slit the glass. You will see that the violet almost entirely disappears, leaving the blue bright, but cutting off the red. We can do the same with the yellow glass, and we find that it cuts off all the violet and a deal of the blue green. We have seen what sort of a white a mixture of the two make, and we can tell what kind of a spectrum they make by rapidly rotating in front of the slit a sector in which are the two glasses

showing proper proportions. We see now the spectrum of the combined lights upon the screen. It is quite different from that of white light, for there is no violet in it, and it has perhaps rather more green blue in it, but this is an advantage, as it shows that the blues will not suffer when viewed in such a light. In fact, a little more predominance, if anything, will be given to the blues. The figure above shows the luminosities of the naked spectrum, and that coming through the yellow and blue glasses. Had I used the ordinary cobalt blue glass, you will see that I should have gained nothing in safety. The spectrum, with such a glass interposed before the slit, is again on the screen.

You will remember that it is a banded spectrum, admitting all the violet and blue, cutting off the green, but allowing a band of yellow and two of red to pass through. As the blue-green glass cuts off the violet, we may take it that it is much safer to use light coming through it than ordinary white light, as far as the fading of pigments is concerned. It was in experimenting with this glass that I came to the conclusion that if we used the light passing through it as one component of a mixed light, and could find a light passing through a yellow glass which would neutralize it, we should have a valuable means of securing greater immunity from fading than we have by using white light alone. The yellow glass I have shown you was selected, not as the most perfect sample, but as being very transparent. If anything, it wanted a trace more red with it, but without it we get a combination which ought to answer every purpose. Let me show you how some pigments look in this light. I place a lens in front of the lantern and make a disk on the screen. Where the rays cross, a rotating sector is placed containing these two glasses, so that the disk is alternately illuminated by the blue green and yellow light. The change is so rapid that the two colors blend one into the other. I place various colored pictures in the beam and note their appearance, and then illuminate them with ordinary white light of the same intensity. We find that the two are almost exactly alike, every color shows in the one as well as in the other, and apparently a difficult problem is solved.

I well remember the first small experiment which I tried with these glasses. It was in a small photographic studio which we have at South Kensington

Museum, erected for the use of outside photographers. A small portion was curtained off and the roof glazed with these glasses in proper proportions. Water color sketches were taken into this light, and critically examined by some whose opinion I highly value. The chairman, for instance, whose exhibit at the New Gallery shows him to be a colorist of no mean order, approved, and so did the director for art, Mr. Armstrong.

So successful was the appearance of the colors, that an experiment on larger dimensions was made by the authorities of the museum when part of the roof of the gallery in which the Jones collection is housed was glazed with these glasses in proper proportions. The public freely circulated through the gallery, and as far as I know the criticisms which were passed were few, and certainly not as a rule condemnatory. The committee of artists, who acted as advisers in art matters to Dr. Russell and myself, when carrying on the investigations as to the fading of pigments, and of which Sir F. Leighton was the chairman, gave it as their opinion that the lighting was satisfactory.

When the Raffaelle Cartoon Gallery was to be reroofed the authorities directed that the glazing should be carried out with these colored glasses, to prevent, as far as possible, any further fading of these valuable works of art. The glazing is in alternate strips of the two colors (some few panes have been glazed with ordinary white glass to allow for slight modifications in the proportions of the two colors, if considered desirable) on the slope of the roof. The light, before coming into the gallery, traverses a flat skylight of corrugated white glass, which distributes and scatters the color, even when sunlight streamed through the colored panes.

It has been a source of amusement to myself to stop in this gallery and note the effect the light produced on the minds of the different parties who passed through it. The large majority of persons saw nothing peculiar about the light, and failed to notice the colored glasses in the roof, while others noticed them and could not understand what they meant. Americans seemed to be those who were most observant. I

have had the advantage of hearing the criticism of several artists regarding the lighting of this cartoon gallery, and the general dictum was that the color and lighting were satisfactory. One artist told me he wished he could always have such a warm light in which to exhibit his pictures. He said it was a most becoming light. In choosing the proportions I was led to make a mixture which imitated as far as possible a mixture between a blue sky light and a warm sunlight. Light from a blue sky is always cold, and light reflected from clouds is, I believe, the illumination artists like. Hence my choice of these. When the light is principally from the blue sky, this meant that the yellow light predominated a little more than it would do when the mixture was made by the electric light. In order to arrive at this color, I took sunlight itself as the standard white, and adjusted the proportions of sky light passing through the two glasses in such a manner that the warmth of a light from a sky partially covered with white clouds was found in the mixture.

It may be of interest to know what the illumination is compared with glazing by white glass, that is, how much is cut off. This can be very readily ascertained by measuring the luminosity of each color coming through the glasses.

We can make the experiment for ourselves.

First I place the yellow glass in one white beam, and alongside it send another beam of white light. By intervening a rod in the paths of the two beams, to cast two shadows, and reducing one by rotating sectors, which can give a larger or smaller aperture at will during rotation, we can arrive at a point where the two shadows are equally luminous.

Removing the glass, the balance is again secured, and we find that in this case the aperture required is 60°, and in the other 85°, showing that the yellow glass allows ⅓⅓ of the white light to pass through it. We can do the same with the blue-green glass, and find it cuts off a deal more, allowing only ⅓ of the light to pass. Now, if half the roof be glazed with yellow glass, and the other half with the blue-green glass, the total light passing through is only 45 per cent. of what would fall through the aperture of the roof if no glass were in it. Absorption and reflection by white glass reduces that loss to about 50 per cent., a great diminution, it is true, but still one

which is made up for in several ways. In the Raffaelle Cartoon Gallery the open area in the new roof is considerably larger than it was in the old roof, and the light is practically the same as it was before. Further, the use of ground glass or blinds is done away with, ribbed glass being substituted. The ribbed glass, as before stated, helps the mixture of the two colors when falling on the pictures.

I do not say that the lighting is perfect and that improvements cannot be made in it. Science never comes to a finality, but I am bold enough to think that it is a step in advance. What may be termed the "fading value" of the light can be readily ascertained. In the diagram before you we have the photographic absorption spectra of the blue-green of the yellow glasses and of the two mixed lights. It will be seen that the violet is totally, or very nearly, inactive. In the ultraviolet there is a carbon band which is intensely active, photographically, in the electric arc light. This is slightly transmitted through the yellow glass, but in sunlight these rays are so weak that they only appear after very prolonged exposure. What the effect is may well be judged by taking an ordinary photograph in this gallery and in the adjoining one. I find that a bromide plate requires nearly ten times the exposure in the former that it does in the latter, when photographing a picture. Bromide of silver, being sensitive to the green, does not show such a difference as chloride of silver does. Here are two pieces of such paper exposed for equal lengths of time, viz., one hour, in each of these galleries. You see that while the piece exposed in the ordinarily lighted room is quite dark, the photographic action appearing on the other is very small.

What the extension of time for fading is I cannot say. Putting it as low as ten times, we have a considerable saving. Thus, a picture which in ordinary light would last ten years will, if hung in this light, last at least 100 years, and probably 200 years. In some calculations made in our report, Dr. Russell and myself stated that it would take 100 years in one of the museum galleries for pigments to arrive at the fading shown by our experiments. Had this glazing been adopted, we should have to have increased this time to at least 1,000 years instead, a time sufficiently long to enable further advances to be made in the knowledge of what will completely hinder all fading.
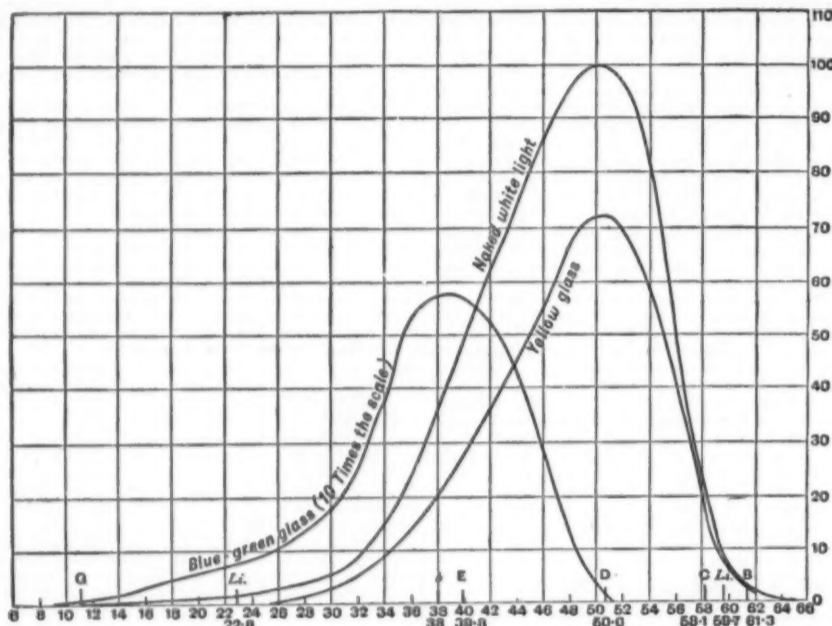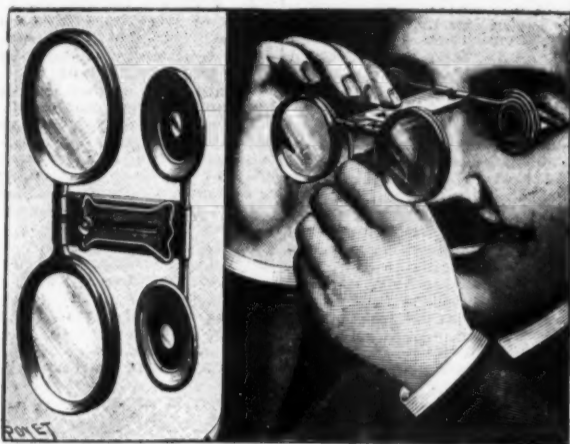
I have now shown you the reasons which led me to experiment with this glazing, and to judge it as efficient. I trust the lighting of this Raffaelle Cartoon Gallery may prove not to be merely a safe experiment, on a large scale, but a real step in the right direction, which, perhaps, may with advantage be adopted elsewhere.

The chairman, in proposing a vote of thanks to Captain Abney for his interesting paper, said the total result of it seemed to be briefly this, that they could not eat their cake and have it. If you had pictures and wanted to use them as pictures and look at them, you must expose them to vibrations; to some of those vibrations the pigments would respond, and to others they would not: but even the latter must produce some stress or strain, which eventually would affect the pigment; but those vibrations to which they responded had the effect of bringing the various molecules into unpleasantly close association with other bodies, from which they had better be kept apart; and the result was that certain changes were produced. Probably the most effectual agency in these changes was moisture, but even excluding moisture, you were still sure to have changes go on, unless, indeed, you locked the colors up absolutely in glass, as in enamel or stained glass, or, as you found in nature, in crystals, as in a sapphire, in which case they would in most, though possibly not in all cases, remain permanent. Otherwise it might almost be said that, in proportion as pigments were exposed, so would changes take place in them; and all you could expect to do was to mitigate the deleterious action of light by exposing the pigments only to such portions of the light as were necessary to enable you to see them, and to exclude those others which were not necessary and which might produce damage. They would all agree that Captain Abney had shown how, by a most ingenious and easily applied process, this could be effected, at all events in public galleries. He did not know whether people would care to have alternate panes of blue and yellow glass in their private rooms, but at all events in public galleries it was apparently a very effective method of preserving pictures, and one which could easily be applied. He must say that when Captain Abney first proposed to glaze the skylights at South Kensington with this blue and yellow glass, he could not help fearing that in a few days there would be some frantic letters in the papers about it, but, fortunately, he did not think many people observed it, and it had now been going on for some time, and it was probably too late now for anybody to make a fuss about it. These results arose from the investigations which Captain Abney undertook with Dr. Russell at the request of the Committee of Council on Education, and about the time they commenced their investigations there was a great deal of discussion in the public press on the fading of water colors, and what was called the "gang" at South Kensington was especially held up to public opprobrium on account of their treatment of water colors. Why they were supposed to be worse than the rest of the world who exhibited pictures, he did not know, but so it was. But he was glad to say that Capt. Abney was still one of the "gang," and they had seen what he had done in the matter. It afforded an illustration of the old proverb, that the best gamekeeper was found in the reclaimed poacher. Certainly, as far as they knew at present, he had devised the most effective method, and one very readily applied, of preserving water colors and oil paintings, and giving them as long a life as possible.

The vote of thanks having been carried unanimously, Captain Abney, in responding, said he would warn those who painted in oil against thinking they were much safer than those who used water colors.

PORTABLE OPERA GLASSES.

THE researches of opticians have for some years been directed toward the construction of portable opera glasses. The United States, which are so fertile in original combinations of all kinds, have, on their part, furnished a certain number of special arrangements to

this end, but now we have a pattern of pocket opera glasses due to Mr. Leo Bloch, a Parisian manufacturer, and which appears to us to be the ne plus ultra of compactness. This instrument, which is cleverly constructed, and the simple mechanism of which renders the operation very easy, is but about three-tenths of an inch in thickness when closed, and is thus capable of being carried in an ordinary card case.

As shown in the figure to the left of the accompanying engraving, the objectives and oculars turn down in the same plane, as does also the movable handle that is used ab libitum for holding the instrument. In order to open the latter, it is held with the left hand by the handle, while with the right hand the objectives and oculars are revolved upon the axis of the rod which serves as a mounting. A stop fixed to each rod limits the rotation both for the opening and closing, while a flat spring holds them in each of these two

POCKET OPERA GLASSES.

extreme positions. The focusing is done with a single hand, by maneuvering the small button with central point that is placed under the slide within reach of the thumb.

Aside from the indisputable originality and convenience of this instrument, it presents the curious feature of not being provided with tubes, and of its definition, nevertheless, not being prejudiced by that fact. The aperture of the diaphragm, the focus, and, consequently, the distance between the oculars and objectives, are so calculated that any casing would be superfluous.

The figure to the right shows the method of using this ingenious apparatus.—La Nature.

DIFFUSING AND PROJECTING GLOBES FOR LAMPS.

WE have already pointed out the value of the application of corrugated globes to lamps of a certain intensity, and have given a description of the types devised to this effect by the Societe Francaise d'Eclairage Holophane.* We think it well to complete these data by speaking of the analogous apparatus devised by Mr. Fredureau and constructed by the Societe Anonyme des Globes Diffuseurs.

As may be seen from the sections shown in the accompanying engraving, these globes are based upon the same principle as the ones already described, and,

DIFFUSING AND PROJECTING GLOBES FOR LAMPS.

like them, are applicable to lamps of all kinds—kerosene, gas or electric.

The arrangement of the corrugations, however, is different, since an endeavor has been more especially made to concentrate the luminous pencil in a determinate direction. The upper surface of each of these corrugations, in fact, is formed of a segment of a paraboloid, while the under surface is plane. The various paraboloids, formed by the union of the corrugations, have as a common axis that of the diffusing globe, and the center of the latter as a focus. From this arrangement it at once results that the luminous rays emanating from the focus and reaching the upper surface of each ring are reflected therefrom parallel with the axis of the paraboloid confused with that of the globe, and make their exit through the lower surface without deflection. The majority of these rays, therefore, illuminate that portion of space situated in the prolongation of the axis of the focus, and generally below the

latter, while the rest are reflected by the next ring below and are diffused. Only a small fraction of the light is refracted in the interior of the globe, and this, moreover, comprises the most refrangible rays, the violet and blue, which are, as well known, those most fatiguing to the eyes. The internal section of the globe is smooth, and thus of itself causes no special refraction. From this explanation it will be understood how it is possible for the arrangement of the corrugations to assure the concentration of the luminous pencil. So in practice it is observed that the placing of this globe upon a naked lamp has the effect of immediately quadrupling the value of the illumination in the direction of the axis of the apparatus. The hemispherical globe thus gives striking results as a projecting apparatus, and this experiment is one of the most striking that could be made.

For public lighting and for the lighting of apart ments the diffusing globes employed are of spherical or rather of cylindro-spherical form, or even tulip shaped, the types of which are analogous to those shown in the figure. These shapes have the effect of concentrating the luminous pencil in the region situated beneath the globe, in reducing principally the quantity of light that is diffused in the lateral directions, without entirely intercepting that which is reflected upward. It is evident, moreover, that the types to be employed should be determined by taking local circumstances into account.

As a consequence of this rational distribution of the light, the diffusing globes have the effect of sparing the eyes by concealing the luminous source from view. For public lighting they thus present the advantage of facilitating the application of powerful lamps, which, as well known, are relatively more economical than those of feeble intensity with which one would otherwise be obliged to be satisfied. Arc lamps, for example, under these circumstances give a light easily supported by the eyes and deprived of its wan tone by the refraction of the blue rays. Let us add that the light is diffused, projected on all sides and seems to be everywhere much better utilized. We shall be able, however, before long to judge of the effect produced in the lighting of the public thoroughfares, since the diffusing globes are to be applied upon some of our large streets, as they were once, moreover, temporarily upon Place de l'Opera, on the occasion of the Franco-Russian fetes of the 20th and 24th of October, 1893.— La Nature.

LIGHT AND ELECTRIFICATION.*

By OLIVER J. LODGE.

IF an ordinary gold leaf electroscope with a freshly scraped zinc cap or knob is charged with negative electricity, and is then exposed to the unfiltered rays of a source of ultra-violet light, its charge will leak away rapidly.

If, further, the electroscope so treated be extremely sensitive, it will be found not only to lose its negative charge, but to acquire a slight trace of positive charge under the action of light.

These are the simple and fundamental facts of what is virtually a new subject or branch of physics, the subject of photo-electric action, the influence of illumination on electrified surfaces.

SUMMARY HISTORICAL SKETCH.

The above facts were discovered by Hallwachs, but their discovery originated in an observation made by Hertz, that the sparking of an induction coil was facilitated when the light of another spark fell upon its secondary terminal. Hertz proved conclusively that this was a real action of light, and not due to some more direct electric action, nor yet to any convection of chemical or dissociated products from one spark to the other, such as Schuster and others have found to be likewise a real and genuine effect having influence on some forms of electric discharge. Hertz also tried other sources of light, and by passing the rays through a quartz prism established the fact that it was the ultra-violet rays which were specially active. In fact, if a thin sheet of glass were interposed, so as to cut off the extreme and invisible ultra-violet rays, the action ceased ; though a layer of water was transparent to the action, except when certain salts were dissolved in it ; while coal gas was remarkably opaque, and stopped the action when interposed in a sufficient stratum between the two sparks. He further modified the experiment by taking the sparks between different metals in different gases, and in air at different pressures. He thus found that in rarefied air the effect was exaggerated, and that an atmosphere of hydrogen was rather better than one of air. He also found that the region of the spark terminals near the negative pole or cathode was the most sensitive part of a spark gap, so that, in fact, the main photo-electric influence depended on whether the region near the cathode surface was or was not illuminated.

The subject was taken up by a number of experimenters, among whom Wiedemann and Ebert specially examined the effect in different gases, and established the fact that the illumination operated only on the cathode surface or negative pole, and that illumination of the anode, or of the air between the terminals, had little or no influence on the discharge. Supplementing this, Hallwachs, and later Hoor, discovered that a freshly cleaned metallic surface lost a negative charge quickly under the action of light, but retained a positive charge ; while Hallwachs and Righi independently and simultaneously discovered that such a freshly cleaned metallic surface, when exposed to light, not only discharged any negative electricity it might possess, but was able actually to acquire a slight positive charge. Lenard and Wolf also made the important observation that a negatively charged or an uncharged metal seemed to evaporate, or throw off something which might be called "dust," under the action of light. Other investigators into the subject who must be mentioned are Stoletow and Branly, but probably none have worked at it more energetically and successfully than the well known coadjutors of Wolfenbuttel, Messrs. Elster and Geitel, who have discovered many remarkable facts in connection with it. It was not till the beginning of 1894 that the subject was seriously taken up by the writer.

This brief outline of some of the work that has been done in this subject since its discovery in 1887 must serve instead of a proper historical sketch, because we want to pass from the consideration of the investigators to a study of the facts themselves.

EXPERIMENTAL DETAILS.

A demonstration of the fundamental fact can be made with very simple appliances, but unless they are properly arranged it is easy to fail. Several experimenters have indeed doubted the fact because they were unable to repeat it. No method can be simpler than the one indicated in the first few lines of this article ; and with a well insulated electroscope, whose rate of leakage can be timed, the only difficulty is the obtaining of a suitable light. Sunlight on a mountain top is certainly effective, but sunlight on a plain is much weaker, and in a British town (perhaps even in the British Isles) it has hardly any power at all ; the active rays are all filtered out by the gross and polluted atmosphere usually existing above such places. Visible brightness of illumination is not what is wanted ; the most effective rays are invisible ; for instance, Hertz observed that the oxyhydrogen flame was just as effective before the lime was introduced into it as after, and that it is the bottom blue part of a candle flame which possesses any power at all ; hence the light from a brush discharge or from the aureole surrounding an induction coil spark is very much more effective than, for instance, the lime light or even the magnesium light. An arc light is, however, the most powerfully active source, especially if it is made extra long, and still more if a little zinc is placed in the positive crater for volatilization. Hertz himself noticed that the violet flame between the poles was more active than the intensely bright carbons themselves. In using the arc lamp it must be understood that it is to be naked. There are to be no lenses in the lantern, or if there are, they must be composed of quartz or other really transparent substance.

The statements here made about the need for extremely ultra-violet rays are, however, subject to modification with the nature of the gas surrounding the metallic surface, for Wiedemann and Ebert found that in an atmosphere of carbonic acid even visible rays produced some effect ; and a still more marked modification is dependent on the nature of the metallic surface. I have spoken of zinc as a suitable metal, and so it is ; but, with highly ultra-violet light, copper, silver, and even platinum, do nearly as well. With light of lower refrangibility, zinc is better than the less oxidizable metals, but, as Elster and Geitel have found, potassium or sodium is better still. With such metals indeed any kind of light serves, not only ordinary diffuse daylight, but even the light of a candle.

INFLUENCE OF THE KIND OF METAL.

It appears that the order of metals in photo-electric power, when tested by their discharging action for negative electricity, is the same as their order in the voltaic series, the alkali metals heading the list, and the noble metals being the least effective. With light of ordinary wave lengths, indeed, such as come easily through glass, only the alkaline metals, or those above zinc in the voltaic series, have any real power ; but with short enough wave lengths all metals are competent to show the effect, though the noble metals require light of an extremely high ultra-violet character.

This fact of the voltaic order of the metals clearly

suggests some chemical or semi-chemical explanation, but it may be well to defer coming to a conclusion on that point for the present.

DISCHARGING ACTION OF METALS FOR POSITIVE ELECTRICITY.

Hitherto we have spoken, as the earlier experimenters in the subject did, as if negative electricity alone was discharged while positive electricity was retained.

If the surfaces are very clean, and if the light is ordinary ultra-violet light, the difference between the rates of discharge of negative and positive electrification is so enormous that it is practically true to say that one pours away while the other is retained; but more careful observation will show that the rate of leakage of positive, too, is usually increased by illumination. The leakage of positive, however, occurs better from surfaces not too recently cleaned, and it appears as if still shorter wave lengths were necessary for it than for leakage of negative.

My experiments go to show that as metals get dirty the rates of leakage of negative and positive become more comparable. And one metal I have found which is able to discharge positive even faster than negative, viz., cobalt. What the meaning of this exceptional behavior may be is quite unknown, but the general rule seems to be that the discharging order of the metals follows the voltaic series, and that the more oxidizable metals discharge negative more easily, and under longer wave lengths, than do the less oxidizable. Righi further finds that the tendency of metals to become positively charged under the action of light likewise follows the voltaic order, but inversely; gold and carbon being more effective in acquiring a positive charge than zinc and aluminum.

It may be doubted whether this is capable of thorough substantiation as a general law or not, but there can be no doubt that the discharge of negative electricity is most rapid from perfectly clean metals; they need not be polished, scratching with sandpaper suffices, but a few minutes' exposure to air destroys the initial extreme vigor of the effect. It is not true that a positive charge is wholly retained under the action of light even by such clean metals; they do discharge it, but very much more slowly than they do a negative charge, whereas, when they are tarnished the rate of discharge for the two kinds of electrification is more nearly equal, and when they are dusty or dirty it is quite possible for positive electricity to be discharged more rapidly than negative by the action of light.

The following extracts from my laboratory note book may serve to establish and illustrate this fact:

Platinum plate dirty with age connected to a measuring electroscope and illuminated by an arc lamp, showed a definite fall of potential when charged negatively, passing from mark to mark on the scale in 120 seconds. When charged positively it showed the same fall of potential in 100 seconds. Platinum plate scratched clean with glass cloth and similarly treated showed the same amount of leak in 6½ seconds when negatively charged, but when positively charged it still took 100 seconds.

Here is another example. A clean zinc plate, the same size as the above platinum, leaked at exactly the same rate in the strong rays of an arc lamp, viz., negative in 6½ seconds, positive in 100 seconds; but when a dirty piece of zinc was employed, the time required for the same amount of leak was 30 seconds for negative and 65 for positive.

Most clean metals on this occasion gave about the same rate of leak, but tin plate seemed rather exceptionally quick. Its rate for negative was 4 seconds and for positive 80 seconds.

THE QUESTION OF FATIGUE.

Lapse of time makes any metallic surface less powerfully photo-electric, simply by reason of tarnishing or accumulation of dust; but the question arises whether light itself has any effect in accelerating this decay of the power. To try this a couple of similar plates have been kept for some hours, one in the blaze of the arc, the other in comparative darkness, and then their rates of leak compared. The only metal which showed a distinct effect of this kind was palladium. Palladium appears to get rapidly fatigued by the action of light, so much so that its fatigue is noticeable in a simple series of leakage experiments taken one after the other.

Another experiment, something of the same sort, was to reflect light down on to the surface being tested by a clean silver-on-glass mirror. The mirror could be kept charged either negatively or positively, and, of course, under these conditions it itself discharged rapidly, especially when negative; but the question was whether light thus reflected from a discharging mirror had become at all inactive or whether it was still equally competent to exert a discharging action on any second surface which it met. The latter seems to be the truth; whatever fatigue may be experienced by a surface, none seems experienced by a light; or if the light was affected, there was too great a balance of power left to make its deterioration of quality conspicuous. It is, however, an important question whether the short waves which are especially operative are really consumed in the act of effecting the electric discharge or whether they are uninjured, and hence the experiment was carefully and repeatedly performed. No question of energy arises, because the energy of the discharge may be simply and entirely electrical.

NON-METALLIC SUBSTANCES.

Elster and Geitel found that luminous paint was peculiarly active as a discharging agent, and they tried other phosphorescent bodies too, also several minerals. In my experience some minerals discharge positive more readily than negative, but any surface to be effective should be dry. A lump of dry soft red sandstone fell in potential a given amount in 150 seconds when charged positively, whereas when charged negatively it fell much more slowly or not all. On the other hand many non-metallic bodies imitate metals in their more rapid loss of negative electricity. Thus a piece of gas carbon lost negative in 18 seconds, positive in 150; lampblack lost negative in 10 seconds, positive in 120.

PLANTS.

Several growing plants, and cuttings of others, were tried in my laboratory last June, with the result that

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several of them discharged positive more readily than negative; but on the whole the rates of discharge for the two kinds of electrification from the leaves of plants under the action of light are more nearly equal than are the rates of discharge from most other substances. Some facts suggest that the time of year, i. e., the state of the plant, has an influence; and we conjecture at present, as the result of observation, that in summer when the leaves are fresh positive electricity is most easily discharged, whereas in late autumn negative seems to gain the advantage. A geranium in a pot was the first thing tried (in June, and it then discharged positive five times as quickly as negative. In all cases it must be understood that the action is due to the ultra-violet rays; glass cuts off the effect, quartz transmits it.

Garden soil was also tried, and when dry it has a very fair discharging power, usually rather quicker for positive than for negative.

TENSION OR POTENTIAL.

In a future article we may endeavor to discuss the physical aspect of some of these facts from the point of view of theory, but it is plain, in the experiments on metals at any rate, how clearly a quasi-chemical origin is indicated for the discharging power. That being so, it is essential to ascertain whether the effect depends on the potential of the electrified metal, or whether it is dependent on surface density. It is easy to have a metallic surface at a high potential without a trace of electric charge; such is the inside of a metallic inclosure, or practically of any highly charged hollow vessel; its surface density and its electric tension will be nothing, though its potential may be thousands of volts. Conversely, it is easy to have a surface charged to a high density and with an electric tension at the point of bursting, while yet its potential shall be zero. This is the case of an earth-connected surface exposed to the inductive influence of a highly charged insulated body.

It is a simple question for experiment to decide whether the discharging power of light operates in one of these cases and not in the other. Or, briefly, does the discharging power of light on a surface depend on the tension or on the potential of that surface?

The answer is distinct; it depends upon tension. If the surface is not actually charged with electricity, light has no effect; or at least its effect is limited to the feeble charging with positive which so many experimenters have observed, and which we may assume at present to be correct; though whether it is a true and simple effect, we will not at present consider quite decided.

The inside of a metallic vessel is not affected by light, even when the air contents are blown out and exchanged for fresh air. Unless the atmosphere is thus changed, the experiment is inconclusive, because, even if a charge were to leave the interior surface of the vessel and pass to the air in contact with it, an electroscope connected to the vessel would, of course, show nothing; the charge must be extracted entirely from the vessel before its potential is affected. However, if proper precautions are taken about blowing in non-electrified air (by no means an easy matter), the experiment is perfectly negative; no discharging action occurs from a surface at zero density.

If the beam of light which has been shining on the interior of a charged pewter pot is transferred and made to impinge on an outer edge of the same vessel, the leak of electricity immediately becomes rapid.

On the other hand, a surface connected to the earth (and, therefore, at zero potential) pours away its induced charge rapidly when a beam of suitable light falls upon it. And, indeed, this is a favorite and easy mode of testing the power of different substances, viz., by exposing them to the inductive influence of a charged body, such as a layer of wire gauze, through which light has easy access, and observing the rate of leak either by the rise in potential of an electroscope attached to them and initially at zero, or by a very sensitive galvanometer inserted in the circuit which connects them to earth. Indeed, with a water battery or other source of high EMF, nothing further is needed than a sensitive galvanometer and the two surfaces facing each other across a narrow air space, which under the action of light becomes virtually conducting.

EFFECT OF MAGNETISM.

One of the most singular observations on the subject was made by Elster and Geitel, who placed the poles of a magnet in various aspects with respect to the line of discharge or of conduction between two plates in vacuo, such as are mentioned just above.

They found that if the lines of magnetic force agreed in direction with the lines of electrostatic force, they had no appreciable influence on the discharging power of light; but that as soon as the magnetic and the electrostatic lines crossed, the discharging power of light was definitely diminished and interfered with.

QUESTION OF INTENSITY OR TOTALITY OF ILLUMINATION.

Experiments made in my laboratory were directed to ascertain whether the action of light depended on its concentration or on its total amount. To this end a large metal plate was set at different distances from the source in a cone of rays, so that at one time a very small area and at another time a larger area was exposed to the same total quantity of light.

No very minutely accurate measurement was possible, because an arc light is subject to capricious variations, the long fizzing are being much the most effective; but certainly if there is any effect due to concentration, it is very small. On the average, the rate of leak was just the same when the light was spread over a large area as over a small.

INFLUENCE OF THE DIRECTION OF THE LUMINOUS VIBRATION.

Another vital discovery was made by the Wolfenbuttel experimenters by aid of their beautiful method of employing the alkali metals for the purpose in partial vacua in glass bulbs. The alkali metals are generally superior to others by reason of the fact that ordinary visible light is powerfully effective in their case, so that glass is no deterrent, and candles or diffuse daylight may be used. This is convenient for measuring purposes, because of their great steadiness as compared with an arc; and another convenience is the

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possibility of using a liquid metallic surface, viz., that of the liquid potassium-sodium alloy. Mercury is comparatively inert, but a liquid surface has the great merit of being perfectly smooth and horizontal; it thus makes easy definite optical experiments on angles of incidence and azimuth of polarization. Employing the potassium sodium alloy in a hydrogen vacuum, Elster and Geitel found that the most effective light is that which is polarized perpendicularly to the plane of incidence, i. e., light whose vibrations have a component normal to the surface. Light vibrations parallel to the surface are comparatively inoperative.

If this be so, of course it follows that with common light normal incidence should be less effective than oblique incidence; and indeed it may be supposed that any effect of normally incident rays might largely be due to the scratched and unpolished state of ordinary metallic surfaces. Experiments conducted in my laboratory on polished surfaces of silver do not bear this out. Normally incident light has a very considerable effect, at least on ordinary surfaces in air, though obliquely incident light has a greater. Using the liquid K—Na alloy it was possible to verify completely Elster and Geitel's result with respect to the azimuth of polarization, and we also found that with common light and different angles of incidence the effect increased rapidly as the incidence changed from normal (0°) to something near 60°, but that it then ceased to increase any more. So far as I have observed, the effect of polarization and varying incidence is much more marked with these alkaline metals in vacuum, than it is with such surfaces as polished zinc or silver in ordinary air and other gases exposed to ultra violet waves; though with these also it is perfectly real and definite.

I have now rehearsed what may be considered as a summary of most of the more prominent and interesting facts connected with the subject, abstaining from any theoretical comment. In a future article the attempt may be made to collate these facts and to consider their bearing with reference to a possible explanation or perception of the meaning of the effect, so far as it is reasonable to suppose it understood at present.

THE RARER METALS AND THEIR ALLOYS.[*]

THE study of metals possesses an irresistible charm for us, quite apart from its vast national importance. How many of us made our first scientific experiment by watching the melting of lead, little thinking that we should hardly have done a bad life's work if the experiment had been our last, provided we had only understood its full significance. How few of us forget that we wistfully observed at an early age the melting in an ordinary fire of some metallic toy of our childhood; and the experiment has, like the "Flat iron for a farthing," in Mrs. Ewing's charming story, taken a prominent place in literature which claims to be written for children. Hans Andersen's fairy tale, for instance, the "History of a Tin Soldier," has been read by children of all ages and of most nations. The romantic incidents of the soldier's eventful career need not be dwelt upon; but I may remind you that at its end he perished in the flames of an ordinary fire, and all that could subsequently be found of him was a small heart-shaped mass. There is no reason to doubt the perfect accuracy of the story recorded by Andersen, who at least knew the facts, though his statement is made in popular language. No analysis is given of the tin soldier; in a fairy tale it would have been out of place, but the latest stage of his evolution is described and the record is sufficient to enable us to form the opinion that he was composed of both tin and lead, certain alloys of which metals will burn to ashes like tinder. His uniform was doubtless richly ornamented with gold lace. Some small amount of one of the rarer metals had probably—for on this point the history is silent—found its way into his constitution, and by uniting with the gold, formed the heart-shaped mass which the fire would not melt, as its temperature could not have exceeded 1,000°; for we are told that the golden rose, worn by the artiste who shared the soldier's fate, was also found unmelted. The main point is, however, that the presence of one of the rarer metals must have endued the soldier with his singular endurance, and in the end left an incorruptible record of him.

This has been taken as the starting point of the lecture, because we shall see that the ordinary metals so often owe remarkable qualities to the presence of a rarer metal which fits them for special work.

This early love of metals is implanted in us as part of our "unsquandered heritage of sentiments and ideals which has come down to us from other ages," and future generations of children will know far more than we do; for the attempt will be made to teach them that even psychology is a branch of molecular physics, and they will therefore see far more in the melted toy than a shapeless mass of tin and lead. It is really not an inert thing; for some time after it was newly cast, it was the scene of intense molecular activity. It probably is never molecularly quiescent, and a slight elevation of temperature will excite in it rapid atomic movement anew. The nature of such movement I have indicated on previous occasions when as now I have tried to interest you in certain properties of metals and alloys.

This evening I appeal incidentally to higher feelings than interest, by bringing before you certain phases in the life history of metals which may lead you to a generous appreciation of the many excellent qualities they possess.

Metals have been sadly misunderstood. In the belief that animate beings are more interesting, experimenters have neglected metals, while no form of matter in which life can be recognized is too humble to receive encouragement. Thus it happens that bacteria, with repulsive attributes and criminal instincts, are petted and watched with solicitude, and comprehensive schemes are submitted to the Royal Society for their development, culture, and even for their "education,"[†] which may, it is true, ultimately make them useful

metallurgical agents, as certain micro-organisms have already proved their ability to produce arseniureted hydrogen from oxide of arsenic.[*]

It will not be difficult to show that methods which have proved so fruitful in results when applied to the study of living things, are singularly applicable to metals and alloys which really present close analogies to living organisms. This must be a new view to many, and it may be said, "it is well known that uneducated races tend to personify or animate external nature," and you may think it strange that the attempt should be made to trace analogies which must appear to be remote, between moving organisms and inert alloys, but "the greater the number of attributes that attach to anything, the more real that thing is."[†] Many of the less known metals are very real to me, and I want them to be so to you; listen to me, then, as speaking for my silent metallic friends, while I try to secure for them your sympathy and esteem.

First, as regards their origin and early history. I fully share Mr. Lockyer's belief as to their origin, and think that a future generation will speak of the evolution of metals as we now do of that of animals, and that observers will naturally turn to the sun as the field in which this evolution can best be studied.

To the alchemists metals were very living indeed; they treated them as if they were, and had an elaborate pharmacopoeia of "medicines" which they freely administered to metals in the hope of perfecting their constitution. If the alchemists constantly draw parallels between living things and metals, it is not because they were ignorant, but because they recognized in metals the possession of attributes which closely resemble those of organisms. "The first alchemists were gnostics, and the old beliefs of Egypt blended with those of Chaldea in the second and third centuries. The old metals of the Egyptians represented men, and this is probably the origin of the homunculus of the middle ages, the notion of the creative power of metals and that of life being confounded in the same symbol."[‡]

Thus Albertus Magnus traces the influence of congenital defects in the generation of metals and of animals, and Basil Valentine symbolizes the loss of metalline character, which we now know is due to oxidation, to the escape from the metal of an indestructible spirit which flies away and becomes a soul. On the other hand, the "reduction" of metals from their oxides was supposed to give the metals a new existence. A poem[§] of the thirteenth century well embodies this belief in the analogies between men and metals, in the quaint lines:

"Homs ont l'estre comme metaulx,
Vie et augment des vegetaulx,
Instinct et sens comme les bruts,
Esprit comme ange en attributes,"

"Men have being"—constitution—like metals; you see how closely metals and life were connected in the minds of the alchemists.

"Who said these old renowns, dead long ago, could make me forget the living world?" are words which Browning places in the lips of Paracelsus, and we metallurgists are not likely to forget the living world; we borrow its definitions, and apply them to our metals. Thus nobility in metals as in men means freedom from liability to tarnish, and we know that the rarer metals, like the rarer virtues, have singular power in enduing their more ordinary associates with firmness, elasticity, strength, and endurance. On the other hand, some of the less known metals appear to be mere "things" which do not exist for themselves, but only for the sake of other metals to which they can be united. This may, however, only seem to be the case because we as yet know so little about them. The question naturally arises, How can the analogies between organic and inorganic bodies be traced? I agree with my colleague at the Ecole des Mines of Paris, Professor Urbain le Verrier, in thinking that it is possible[‖] to study the biology, the anatomy, and even the pathology of metals.

The anatomy of metals—that is, their structure and framework—is best examined by the aid of the microscope, but the method of autographic pyrometry, which I brought before you in a Friday evening lecture delivered in 1891, is rendering admirable service in enabling both the biology and pathology of metals to be studied, for just as in biological and pathological phenomena vital functions and changes of tissue are accompanied by a rise or fall in temperature, so molecular changes in metals are attended with an evolution or absorption of heat. With the aid of the recording pyrometer we now "take the temperature" of a mass of metal or alloy in which molecular disturbance is suspected to lurk, as surely as a doctor does that of a patient in whom febrile symptoms are manifest.

It has, moreover, long been known that we can submit a metal or an alloy in its normal state to severe stress, record its power of endurance, and then, by allowing it to recover from fatigue, enable it to regain some, at least, of its original strength. The human analogies of metals are really very close indeed, for, as is the case with our own mental efforts, the internal molecular work which is done in metals often strengthens and invigorates them. Certain metals have a double existence, and, according to circumstances, their behavior may be absolutely harmful or entirely beneficial.

The dualism we so often recognize in human life becomes allotropism in metals, and they, strangely enough, seem to be restricted to a single form of existence if they are absolutely free from contamination, for probably an absolutely pure metal cannot pass from a normal to an allotropic state. Last, it may be claimed that some metals possess attributes which are closely allied to moral qualities, for, in their relations with other elements, they often display an amount of discrimination and restraint that would do credit to sentient beings.

Close as this resemblance is, I am far from attributing consciousness to metals, as their atomic changes result from the action of external agents, while the conduct of conscious beings is not determined from without, but from within. I have, however, ventured to offer the introduction of this lecture in its present form, because any facts which lead us to reflect on the unity of plan in nature will aid the recognition of the complexity of atomic motion in metals upon which it is needful to insist.

The foregoing remarks have special significance in relation to the influence exerted by the rarer metals on the ordinary ones. With exception of the action of carbon upon iron, probably nothing is more remarkable than the action of the rare metals on those which are more common; but their peculiar influence often involves, as we shall see, the presence of carbon in the alloy.

Which, then, are the rarer metals, and how may they be isolated? The chemist differs somewhat from the metallurgist as to the application of the word "rare." The chemist thinks of the "rarity" of a compound of a metal; the metallurgist rather of the difficulty of isolating the metal from the state of combination in which it occurs in nature.

The chemist, in speaking of the reactions of salts of the rarer metals, in view of the wide distribution of limestone and pyrolusite, would hardly think of either calcium or manganese as being among the rarer metals. The metallurgist would consider pure calcium or pure manganese to be very rare. I have only recently seen comparatively pure specimens of the latter.

The metals which, for the purposes of this lecture, may be included among the rarer metals are: (1) those of the platinum group, which occur in nature in the metallic state; and (2) certain metals which in nature are usually found as oxides or in an oxidized form of some kind, and these are chromium, manganese, vanadium, tungsten, titanium, zirconium, uranium, molybdenum (which occurs, however, as sulphide). Incidental reference will be made to nickel and cobalt.

Of the rare metals of the platinum group I propose to say but little. We are indebted for a magnificent display of them in the library to my friends, Messrs. George and Edward Matthey and to Mr. Sellon, all members of a great firm of metallurgists. You should specially look at the splendid mass of palladium, extracted from native gold of the value of £2,500 000, at the melted and rolled iridium, and at the masses of osmium and rhodium. No other nation in the world could show such specimens as these, and we are justly proud of them.

These metals are so interesting and precious in themselves that I hope you will not think I am taking a sordid view of them by saying that the contents of the case exhibited in the library are certainly not worth less than ten thousand pounds.

As regards the rarer metals which are associated with oxygen, the problem is to remove the oxygen, and this is usually effected either by affording the oxygen an opportunity for uniting with another metal or by reducing the oxide of the rare metal by carbon, aided by the tearing effect of an electric current. In this crucible there is an intimate mixture in atomic proportions of oxide of chromium and finely divided metallic aluminum. The thermo-junction (A, Fig. 1) of the pyrometer which formed the subject of my last Friday evening lecture here is placed within the crucible, B, and the spot of light, C, from the galvanometer, D, with which it is connected, indicates on the screen that the temperature is gradually rising. You will observe that as soon as the point marked 1010° is reached, energetic action takes place; the temperature suddenly rising above the melting point of platinum, melts the thermo-junction, and the spot of light swings violently; but if the crucible be broken open, you will see that a mass of metallic chromium has been liberated.

The use of alkaline metals in separating oxygen from other metals is well known. I cannot enter into its history here, beyond saying that if I were to do so, frequent references to the honored names of Berzelius, Wöhler and Winkler would be demanded.[*]

Mr. Vautin has recently shown that granulated aluminum may readily be prepared, and that it renders great service when employed as a reducing agent. He has lent me many specimens of rarer metals which have been reduced to the metallic state by the aid of this finely granulated aluminum; and I am indebted to his assistant, Mr. Picard, who was lately one of my own students at the Royal School of Mines, for aid in the preparation of certain other specimens which have been isolated in my laboratory at the mint.

The experiment you have just seen enables me to justify a statement I made respecting the discriminating action which certain metals appear to exert. The relation of aluminum to other metals is very singular. When, for instance, a small quantity of aluminum is present in cast iron, it protects the silicon, manganese and carbon from oxidation.[†] The presence of silicon in aluminum greatly adds to the brilliancy with which aluminum itself oxidizes and burns.[‡] It is also asserted that aluminum, even in small quantity, exerts a powerful protective action against the oxidation of the silver zinc alloy which is the result of the desilverization of lead by zinc.

Moreover, heat aluminum in mass to redness in air, where oxygen may be had freely, and a film of oxide which is formed will protect the mass from further oxidation. On the other hand, if finely divided aluminum finds itself in the presence of an oxide of a rare metal, at an elevated temperature, it at once acts with energy and promptitude, and releases the rare metal from the bondage of oxidation. I trust, therefore, you will consider my claim that a metal may possess moral attributes has been justified. Aluminum, moreover, retains the oxygen it has acquired with great fidelity, and will only part with it again at very high temperatures, under the influence of the electric arc in the presence of carbon.

[A suitable mixture of red lead and aluminum was placed in a small crucible heated in a wind furnace, and in two minutes an explosion announced the termination of the experiment. The crucible was shattered to fragments.]

The aluminum loudly protests, as it were, against being intrusted with such an easy task, as the heat engendered by its oxidation had not to be used in melting a difficultly fusible metal like chromium, the melting point of which is higher than that of platinum.

It is admitted that a metal will abstract oxygen from another metal if the reaction is more exothermic than that by which the oxide to be decomposed was originally formed. The heat of formation of alumina is 391 calories, that of oxide of lead is 51 calories; so that it might be expected that metallic aluminum, at an elevated temperature, would readily reduce oxide of lead to the metallic state.

The last experiment, however, proved that the reduction of oxide of lead by aluminum is effected with explosive violence, the temperature engendered by the reduction being sufficiently high to volatilize the lead. Experiments of my own show that the explosion takes place with much disruptive power when aluminum reacts on the oxide of lead in vacuo, and that if
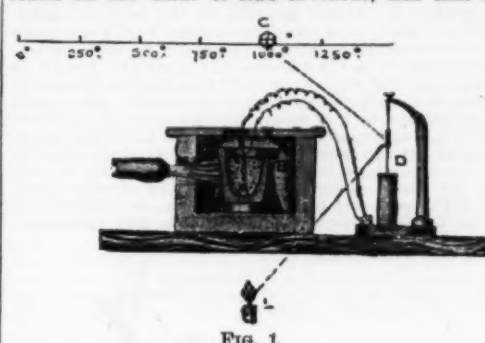

FIG. 1.

coarsely ground, fused litharge be substituted for red lead, the action is only accompanied by a rushing sound. The result is, therefore, much influenced by the rapidity with which the reaction can be transmitted throughout the mass. It is this kind of experiment which makes us turn with such vivid interest to the teaching of the school of St. Claire Deville, the members of which have rendered such splendid services to physics and metallurgy. They do not advocate the employment of the mechanism of molecules and atoms in dealing with chemical problems, but would simply accumulate evidence as to the physical circumstances under which chemical combination and dissociation take place, viewing these as belonging to the same class of phenomena as solidification, fusion, condensation and evaporation. They do not even insist upon the view that matter is minutely granular, but in all cases of change of state, make calculations on the basis of work done, viewing changed "internal energy" as a quantity which should reappear when the system returns to the initial state.

A verse, of some historical interest, may appeal to them. It occurs in an old poem to which I have already referred as being connected with the Roman de la Rose, and it expresses nature's protest against those who attempt to imitate her works by the use of mechanical methods. The "argument" runs thus:

"Comme nature se complaint,
Et dit sa douleur et son plaint,
A ung sot soffleur sophistique,
Qui n'use que d'art mechanique."

If the "use of mechanical art" includes the study of chemistry on the basis of the mechanics of the atoms I may be permitted to offer the modern school the following rendering of nature's plaint:

"How nature sighs without restraint,
And grieving makes her sad complaint
Against the subtle sophistry
Which trusts atomic theory."

An explosion such as is produced when aluminum and oxide of lead are heated in presence of each other, which suggested the reference to the old French verse, does not often occur, as in most cases the reduction of the rarer metals by aluminum is effected quietly.

Zirconium is a metal which may be so reduced. I have in this way prepared small quantities of zirconium from its oxide, and have formed a greenish alloy of extraordinary strength by the addition of $\frac{1}{16}$ per cent. of it to gold, and there are many circumstances which lead to the belief that the future of zirconium will be brilliant and useful. I have reduced vanadium and uranium from its oxide by means of aluminum as well as manganese, which is easy, and titanium, which is most difficult. Tungsten, in fine specimens, is also before you, and allusion will be made subsequently to the uses of these metals. At present I would draw your attention to some properties of titanium which are of special interest. It burns with brilliant sparks in air; and as few of us have seen titanium burn, it may be well to burn a little in this flame. [Experiment performed.] Titanium appears to be, from the recent experiments of M. Moissan, the most difficultly fusible metal known; but it has the singular property of burning in nitrogen—it presents, in fact, the only known instance of vivid combustion in nitrogen.[*]

Titanium may be readily reduced from its oxide by the aid of aluminum. Here are considerable masses, sufficiently pure for many purposes, which I have recently prepared in view of this lecture.

The other method by which the rarer metals may be isolated is that which involves the use of the electrical furnace. In this connection the name of Sir W. Siemens should not be forgotten. He described the use of the electric arc furnace in which the carbons were arranged vertically, the lower carbon being replaced by a carbon crucible, and in 1882 he melted in such a furnace no less than ten pounds of platinum during an experiment at which I had the good fortune to assist. It may fairly be claimed that the large furnaces with a vertical carbon in which aluminum and other metals are now reduced by the combined electro-

* Dr. Brauner. Chem. News, Feb. 15, 1895, p. 79.
† Lotze, "Metaphysic," § 49, quoted by Illingworth. "Personality, Human and Divine," Bampton Lectures, 1894, p. 42.
‡ Berthelot, Les origines des alchimie, 1885, p. 60.
§ Les Remonstrances ou la complaint de nature a l'alchimist errant. Attributed to Jehan de Meung, who with Guillaume de Lorris wrote the Roman de la Rose. M. Meon, the editor of the edition of 1814 of this celebrated work, doubts, however, whether the attribution of the complaint de nature to Meung is correct.
‖ "La Metallurgie in France," 1894, p. 2.

* An interesting paper, by H. F. Keller, on the reduction of oxides of metals by other metals, will be found in the Journal of the American Chemical Society, December, 1894, p. 833.
† Bull. Soc. Chi. Paris, vol. xi, 1894, p. 377.
‡ "Ditte Lecons sur les Metaux," part ii, 1891, p. 306.

* Lord Rayleigh has since stated that titanium does not combine with argon; and M. Gunts points out that lithium in combining with nitrogen produces incandescence.

lytic action and tearing temperature of the arc, are the direct outcome of the work of Siemens.

In the development of the use of the electric arc for the isolation of the rare, difficultly fusible, metals Moissan stands in the front rank. He points out * that Deprez † used in 1849 the heat produced by the arc of a powerful pile; but Moissan was the first to employ the arc in such a way as to separate its heating effect from the electrolytic action it exerts. This he does by placing the poles in a horizontal position, and by reflecting their heat into a receptacle below them. He has shown, in a series of classical researches, that employing 800 amperes and 110 volts a temperature of at least 3,500 degrees may be attained, and that many metallic oxides which until recently were supposed to be irreducible may be readily made to yield the metal they contain.‡

A support or base for the metal to be reduced is needed, and this is afforded by magnesia, which appears to be absolutely stable at the utmost temperatures of the arc. An atmosphere of hydrogen may be employed to avoid oxidation of the reduced metal, which, if it is not a volatile one, remains at the bottom of the crucible almost always associated with carbon —forming, in fact, a carbide of the metal. I want to show you the way in which the electric furnace is used, but unfortunately the reductions are usually very tedious, and it would be impossible to actually show you much if I were to attempt to reduce before you any of the rarer metals; but as the main object is to show you how the furnace is used, it may be well to boil some silver at a temperature of some 2500°, and subsequently to melt chromium in the furnace (Fig. 2). This furnace consists of a clay receptacle,
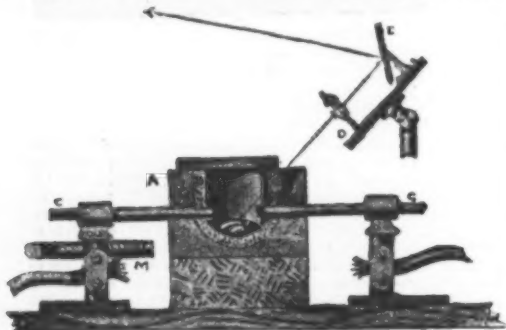
FIG. 2.

A, lined with magnesia, B. A current of 60 amperes and 100 volts is introduced by carbon poles, C, C; an electro-magnet, M, is provided to deflect the arc on to the metal to be melted. [By means of a lens and mirror, D, E, the image of the arc and of the molten metal was projected on to a screen. For this purpose it was found convenient to make the furnace much deeper than would ordinarily be the case.]

It must not be forgotten that the use of the electric arc between carbon poles renders it practically impossible to prepare the rare metals without associating them with carbon, often forming true carbides; but it is possible in many cases to separate the carbon by subsequent treatment. Moissan has, however, opened up a vast field of industrial work by placing at our disposal practically all the rarer infusible metals which may be reduced from oxides, and it is necessary for us now to consider how we may best enter upon our inheritance. Those members of the group which we have known long enough to appreciate are chromium and manganese, and these we have only known free from carbon for a few months. In their carburized state they have done excellent service in connection with the metallurgy of steel; and may we not hope that vanadium, molybdenum, titanium and uranium will render still greater services? My object in this lecture is mainly to introduce you to these metals, which hitherto few of us have ever seen except as minute cabinet specimens, and we are greatly indebted to M. Moissan for sending us beautiful specimens of chromium, vanadium, uranium, zirconium, tungsten, molybdenum and titanium. [These were exhibited.]

The question naturally arises: Why is the future of their usefulness so promising? Why are they likely to render better service than the common metals with which we have long been familiar? It must be confessed that as yet we know but little what services these metals will render when they stand alone; we have yet to obtain them in a state of purity, and have yet to study their properties, but when small quantities of any of them are associated or alloyed with other metals, there is good reason to believe that they will exert a very powerful influence. In order to explain this, I must appeal to the physical method of inquiry to which I have already referred.

It is easy to test the strength of a metal or of an alloy; it is also easy to determine its electrical resistance. If the mass stands these tests well its suitability for certain purposes is assured; but a subtile method of investigation has been afforded by the results of a research intrusted to me by a committee of the Institution of Mechanical Engineers, over which Dr. Anderson, of Woolwich, presides. We can now gather much information as to the way in which a mass of metal has arranged itself during the cooling from a molten condition, which is the necessary step in fashioning it into a useful form; it is possible to gain insight into the way in which a molten mass of a metal or an alloy molecularly settles itself down to its work, so to speak, and we can form conclusions as to its probable sphere of usefulness.

The method is a graphic one, such as this audience is familiar with, for Prof. Victor Horsley's traces on smoked paper may form in a masterly way that traces on smoked paper may form

* Ann. de Chim. et de Phys., vol. iv, 1895, p. 365.

† Comptes Rendus, vol. xxix, 1849, p. 48, 345, 712.

‡ The principal memoirs of M. Moissan will be found in the Comptes Rendus, vol. cxv, 1892, p. 1031; ibid. vol. xvi, 1893, pp. 347, 349, 549, 1222, 1225, 1498; ibid. vol. cxix, 1894, pp. 15, 20, 905; ibid. vol. cxx, 1895, p. 290. The more important of the metals he has isolated are uranium, chromium, manganese, zirconium, molybdenum, tungsten, vanadium, and titanium. There is an important paper by him on the various forms of the electric furnace in the Ann. de Chim. et de Phys., vol. iv, 1895, p. 365.

the record of the heart's action under the disturbing influence caused by the intrusion of a bullet into the human body. I hope to show you by similar records the effect, which though disturbing is often far from prejudicial, of the introduction of a small quantity of a foreign element into the "system" of a metal, and to justify a statement which I made earlier, as to the applicability of physiological methods of investigation to the study of metals. In order that the nature of this method may be clear, it must be remembered that if a thermometer or pyrometer, as the case may be, is plunged into a mass of water or of molten metal, the temperature will fall continuously until the water or the metal begins to become solid; the temperature will then remain constant until the whole mass is solid, when the downward course of the temperature is resumed. This little thermo-junction is plunged into a mass of gold; an electric current is in popular language generated, and the strength of the current is proportional to the temperature to which the thermo-junction is raised; so that the spot of light from a galvanometer to which the thermo-junction is attached enables us to measure the temperature, or, by the aid of photography, to record any thermal changes that may occur in a heated mass of metal or alloy.

It is only necessary for our purpose to use a portion of the long scale, and to make that portion of the scale movable. Let me try to trace before you the curve of the freezing of pure gold. It will be necessary to mark the position occupied by the movable spot of light at regular intervals of time during which the gold is near 1045°, that is, while the metal is becoming solid. Every time a metronome beats a sec-
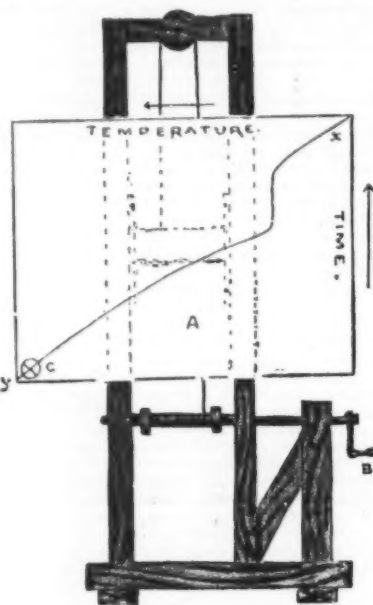

FIG. 3.

ond, the white screen, A (Fig. 3), a sheet of paper will be raised a definite number of inches by the gearing and handle, B, and the position successively occupied by the spot of light, C, will be marked by hand.

You see that the time temperature curve, x, y, so traced is not continuous. The freezing point of the metal is very clearly marked by the horizontal portion. If the gold is very pure the angles are sharp, if it is impure they are rounded. If the metal had fallen below its freezing without actually becoming solid, that is, if superfusion or surfusion had occurred, then there would be, as is often the case, a dip where the freezing begins, and then the temperature curve rises suddenly.

If the metal is alloyed with large quantities of other metals, then there may be several of these freezing points, as successive groups of alloys fall out of solution. The rough diagrammatic method is not sufficiently delicate to enable me to trace the subordinate points, but they are of vital importance to the strength of the metal or alloy, and photography enables us to detect them readily.

Take the case of the tin-copper series; you will see that as a mass of tin-copper alloy cools there are at least two distinct freezing points. At the upper one the main mass of the fluid alloy became solid, at the lower, some definite group of tin and copper atoms fall out, the position of the lower point depending upon the composition of the mass.

(To be continued.)

MINERAL AND METAL PRODUCTION OF THE UNITED STATES IN 1893 AND 1894.

THE accompanying table will give some idea of the extent and variety of the mineral production of the United States. This table, which gives the output of all the chief articles of mineral production for the two years named and of their approximate value, has been compiled for volume III of "The Mineral Industry, its Statistics, Technology and Trade," forming the yearly statistical supplement to the Engineering and Mining Journal. When it is remembered that the table covers a period of depression in trade, of limited demand and general curtailment of all producing industries, the reader will be still better able to appreciate the enormous value and the great variety of the production of the mineral industry.

While no statistics of this kind collected from a country as large as our own and with as varied industries can be absolutely correct, it is believed that these figures are the most accurate and the fullest that have ever been presented of the mines, quarries and metallurgical works of the United States.

Returns have been received in each department from all the producers and these have been carefully

checked and compared with all available sources of information. The statistics of production of several articles as published a year ago in volume II of "The Mineral Industry" have been revised by later and more complete data. It is the intention to render these statistics accurate and trustworthy, consequently when any errors or omissions are discovered they are corrected in subsequent volumes; in this way this work can always be looked to as containing the most accurate statistics of the mineral industry of the world.

The total value of the mineral products of the country, as shown in this table, was $615,887,108 in 1893, and $553,352,996 in 1894; showing a decrease in values (not quantities) last year of $62,534,112, or 10 per cent.

To arrive at the net value of the mineral and metal production in each year, a deduction must be made from the total for that of substances, the value of which has necessarily been duplicated in the tables. Such for instance are the antimony ore used in making the metal; the bauxite used in making alum and aluminum; the coal—chiefly slack—used in making coke; the copper used in making sulphate; most of the lead used in making white lead; the manganese ore used in making spiegeleisen and ferromanganese, which are included in pig iron; zinc used in making zinc oxide, etc.

A careful estimate of the proper amount of these deductions gives $13,000,000 in 1894, and $15,000,000 in 1893, which would leave the net total value of our mineral production in 1893 equivalent to $600,887,108; and in 1894 equivalent to $540,352,996.

To make a fair comparison between the two years, the quantities of the several articles produced should be examined. It is impossible, of course, to give any total in quantities when so many materials and different units of measure are taken into consideration. The only total that can be given is that of values, and the decrease in this amount is in most cases very much greater than the falling off in actual quantities produced. The year 1894 will long be remembered as one of low prices and in almost every industry values were brought down to a point lower than had ever been before known. It was a repetition of the experience of former panic periods, only intensified in our own case by the general distrust provoked by the condition of the currency. It seems to be an unavoidable result of the concentration of capital and the continual improvement in processes which characterize the present age, that production should increase in a greater ratio than consumption, and that at greater or less intervals there should be a period when a halt must be called until the demand can again increase to the level of the supply; and 1894 being one of those periods, the producers suffered accordingly.

It is, however, a proof of the comparatively small amount of the excess in supply that the quantities produced of the leading materials last year show a much less decrease than has been generally believed, even by well informed persons. To take a few leading items, for instance, the production of bituminous coal, which is really an index to the condition of the manufacturing industry, showed a decrease from 1893, notwithstanding the strikes which prevailed, of only 11,000,000 tons, or about 9 per cent., while that of anthracite coal actually increased by 4,700,000 tons, or nearly 10 per cent.; so that the decrease in the total output of fuel was less than 6,221,000 tons, or 3½ per cent., while the decline in value was 7 per cent. In pig iron the decrease was comparatively small, only about 400,000 tons, and we find that all this loss was in the earlier part of the year, while at the close of 1894 the furnaces were running at a rate which promises to make the production of 1895 exceed 9,000,000 tons, which has thus far been the highest mark of our production. In some other important metals again there was an actual increase, amounting in the case of copper to 26,250,000 pounds. In this metal the decline in home consumption was offset by a large increase in the exports.

The silver production of the United States was maintained at a much higher level than had generally been expected, or than had been predicted by many persons who should be well acquainted with the industry. In 1893 the production was 60,500,000 ounces, a decrease of 4,500,000 ounces from 1892, when it had reached its highest level. The low price with which 1894 opened and the withdrawal of the artificial demand created by the Sherman law led many persons to believe that the reduction would approximate the amount of the government purchases under that law, or 54,000,000 ounces, which would have been equivalent to practically wiping out the industry. The actual decrease in 1894 was only 10,654,000 ounces, or about 18 per cent. The reduction still leaves the United States the greatest silver producer in the world, and the industry is, and doubtless will continue to be, a most important one.

Perhaps the most notable feature of the year is the increase in the output of gold. From time to time throughout 1894 the diversion of capital and labor from silver to gold mining has been noted. Not only have many new gold discoveries been recorded, but in many cases also old mines which have been abandoned because they would not pay with the wasteful and defective methods of early days have been reopened with prospects of success under better and more careful methods. The full effect of this revival, however, will not be felt until 1895, and the increase in the gold output has somewhat disappointed the general expectancy, although hardly that of careful observers. The total output of gold in the United States last year was $39,761,000, an increase of $3,806,000 over 1893 and of $6,764,000 over 1892. In gold output Australia has also shown a considerable gain, and runs the United States quite closely this year, while the phenomenal increase from the Transvaal mines has also made South Africa a close competitor for the first rank as a producer of the yellow metal.

To illustrate what we have said with regard to the comparison of values, it will perhaps be well to take a few instances from the table. Thus, while our total production of copper showed an increase of 26,250,000 lb., the estimated value at the place of production was lower by $1,640,000 in 1894 than in 1893. Again, the production of zinc decreased only 2,250 tons or about 3 per cent., while the value reported was less by about $1,000,000 or 16·6 per cent. The decrease in the production of pig iron was 386,000 tons or 5·5 per cent., while the decrease in value was $21,900,000 or nearly 24 per

MINERAL PRODUCTION OF THE UNITED STATES, 1893 and 1894.

Compiled for THE MINERAL INDUSTRY, Vol. III.,
By Richard P. Rothwell, editor of "The Engineering and Mining Journal."

No.	Products.	Customary Measures.	1893.			1894.		
			Quantity.		Value at Place of Production.	Quantity.		Value at Place of Production.
			Customary Measures.	Metric Tons.		Customary Measures.	Metric Tons.	
	NON-METALLIC.							
	Abrasives—							
1	Corundum and emery...	Short tons....	1.747	1,585	$140,580	1,220	1.106	$109,500
2	Garnet.................	"	1,520	1,879	55,800	1,000	907	35,000
3	Grindstones..........	"	45,340	41,133	345,920	37,400	33,932	335,800
4	Millstones............	"	155	141	2,359	297	269	4,447
5	Tripoli and infus. earth..	"	1,351	1,226	25,625	1,802	1,634	36,687
6	Whetstones...........	"	1,905	1,726	89,550	1,735	1,574	84,450
7	Alum.................	"	96,000	87,093	2,880,000	72,000	65,304	2,160,000
8	Antimony ore........	"	850	771	41,000	165	150	9,075
	Asbestos and Talc—							
9	Asbestos.............	"	120	109	6,000	250	227	3,750
10	Fibrous talc.........	"	36,500	33,113	387,625	39,600	35,917	396,000
11	Talc and soapstone...	"	20,160	18,285	366,825	21,044	19,087	401,892
12	Asphalt..............	"	3,490	3,166	68,682	4,498	4,080	75,654
13	Bituminous rock......	"	31,404	28,489	114,782	34,199	25,018	148,120
14	Barytes..............	"	26,632	24,161	133,160	23,738	21,548	95,082
15	Bauxite..............	Long tons.	19,041	10,896	55,905	10,732	10,906	42,986
16	Borax...............	Pounds...	9,190,000	4,173	649,925	13,140,589	5,962	919,841
17	Bromine.............	"	348,289	158	87,100	379,484	172	98,655
18	Cement, natural hydraulic	Bbls., 300 lbs.	7,445,950	913,677	5,010,958	7,895,259	1,074,179	4,897,407
19	Cement, Portland.....	"	673,969	91,715	1,052,173	738,196	100,352	1,080,644
20	Clay, refractory......	Short tons..	3,214,989	2,916,591	4,822,483	3,375,738	3,061,794	4,050,885
21	Clay, kaolin.........	"	30,183	27,392	205,667	24,552	22,346	185,169
22	Coal, anthracite......	"	47,355,387	42,969,116	74,605,985	52,010,433	47,182,345	80,879,404
23	Coal, bituminous.....	"	a128,805,364	116,969,397	128,899,415	a117,950,348	106,956,311	103,842,467
24	Coke................	"	8,939,961	8,104,302	14,706,544	8,495,298	7,706,846	12,654,558
25	Cobalt oxide.........	Pounds....	3,894	2	5,452	6,550	3	8,843
26	Copperas.............	Short tons.	17,862	16,204	134,520	14,897	13,511	104,160
27	Copper sulphate......	Pounds.....	54,000,000	24,492	1,622,500	c60,000,000	27,215	2,016,000
28	Chrome ore..........	Long tons..	1,829	1,646	16,000	2,853	2,697	25,125
29	Feldspar.............	"	17,000	17,374	85,000	23,280	23,655	116,400
30	Fluorspar............	Short tons.	9,700	8,800	63,070	9,000	8,165	64,000
31	Graphite.............	Pounds.....	882,912	400	39,731	770,846	349	34,689
32	Graphite, amorphous.	"	1,891	1,534	8,596	165	150	1,252
33	Gypsum..............	"	330,231	299,682	927,615	287,517	279,437	849,925
34	Lime................	Bbls., 200 lbs.	c60,000,000	5,443,164	30,000,000	c56,750,000	5,104,355	28,375,000
35	Magnesite...........	Short tons.	1,143	1,037	8,000	1,370	1,243	4,864
36	Manganese ore.......	Long tons..	9,150	9,297	60,000	11,785	11,924	74,890
37	Mica, ground........	Pounds.....	679,000	308	29,522	809,500	377	35,987
38	Mica, sheet..........	"	6,500	3	5,478	9,900	4	11,105
39	Monazite............	"	130,000	59	7,600	750,000	340	45,000
40	Natural gas..........				14,000,000			11,000,000
41	Paints, mineral......	Short tons.	44,700	40,550	736,160	38,801	34,301	662,262
42	Paints, vermilion....	"	37	34	40,000	41	37	45,600
43	Paints, white lead...	"	88,500	80,286	9,469,500	87,942	78,155	8,445,174
44	Paints, zinc oxide....	"	25,000	22,679	1,875,000	24,514	22,173	1,711,275
45	Petroleum (crude)....	Bbls., 42 gals.	50,340,228	6,978,403	32,223,505	48,527,396	6,725,490	40,762,962
46	Phosphate rock......	Long tons..	981,340	997,140	3,434,590	962,155	967,485	2,856,465
47	Marls...............	"	200,000	203,814	540,000	225,000	228,622	607,500
48	Precious stones......				200,000			250,000
49	Pyrites..............	Long tons..	95,000	96,536	395,000	107,462	109,192	466,466
50	Salt, evaporated.....	Bbls., 280 lbs.	9,705,419	1,232,362	4,945,983	9,161,053	1,163,508	4,698,375
51	Salt, rock...........	"	1,935,642	245,828	678,064	2,341,922	297,438	788,561
52	Silica, sand and quartz.	Long tons.	300,000	304,814	330,894	315,531	320,610	347,951
53	Slate, roofing.......	Squares.	803,887	237,014	2,956,905	698,944	204,656	2,551,959
54	Slate, other manufactures.	Square feet.	4,138,920		475,681	5,099,791		499,575
55	Soda, natural........	Short tons.	2,500	2,268	12,500			
56	Soda, natural sulphate.	"	90	82				
57	Stone, limestone (flux).	Long tons.	3,750,000	3,810,375	2,250,000	3,544,393	3,602,290	2,126,636
58	Stone, marble........	Cubic feet.	5,639,681	429,899	2,087,758	5,681,706	433,063	2,177,280
59	Stone, onyx.........	"	2,175	166	28,750	1,450	110	29,000
60	Other building stones.				c98,000,000			c90,000,000
	Total non-metals....				377,517,086			353,760,877
	METALS.							
61	Aluminum............	Pounds.....	a312,000	142	202,800	817,600	371	490,560
62	Antimony............	Short tons.	350	318	63,000	230	205	39,300
63	Copper..............	Pounds.....	327,255,788	148,441	35,179,997	353,504,314	110,483	33,540,489
64	Gold................	Troy ounces.	1,739,323	*75,764	35,955,000	1,923,619	*72,732	39,761,205
65	Iron, pig...........	Long tons..	7,043,344	7,156,789	98,898,309	6,657,388	6,764,572	71,960,364
66	Lead, value at New York.	Short tons.	166,678	152,060	12,434,178	160,567	145,906	10,565,048
67	Nickel, fine.........	Pounds.....	25,893	*11,745	12,429			
68	Quicksilver..........	Flasks, 76½ lbs.	30,164	1,046	1,108,527	30,440	1,056	1,095,840
69	Silver, commercial value.	Troy ounces.	60,500,000	*1,881,550	47,311,000	49,846,875	*1,550,238	31,403,531
70	Zinc spelter.........	Short tons.	76,255	69,178	6,214,782	74,004	67,185	5,309,882
	Total metals........				232,370,022			194,092,119
	Est. products unspecified.				6,000,000			5,500,000
	Grand total.........				615,887,108			553,352,996

(a) Including brown coal, lignite.   * Kilograms.
(c) Estimated.

cent.; many similar instances might be taken from the table to show that the total reduction in value of the mineral production of $62,534,112, or 10 per cent., represented very much less than that proportion—probably not over 5 or 6 per cent.—in actual quantities produced.

To sum up the matter briefly, the table given herewith shows a moderate decrease in production, a much larger proportional decrease in the value or prices, but in both cases a decrease upon the whole less than the general expectation of its amount. It shows also that in a year of extremely unfavorable conditions the mineral production of the United States by its extent and variety still gives the country the foremost place among the nations of the world—a place which is, above all, surprising, when we consider the comparatively brief period in which the industry has been built up.

In conclusion we are happy to say that the conditions under which the year closes were far more favorable than those with which it opened. The year 1895 is already beginning to show a very great improvement over its predecessor, and we are warranted in hoping that 1896 in its turn will show a development exceeding any which has yet been seen in the history of the mineral industry.—Engineering and Mining Journal.

THE NEW ELEMENT HELIUM.

THE latest debutante in the scientific arena is the new element helium, lately discovered by Professor Ramsay, of the University College, London, England. The above metaphor is well suited to this new element, for just as society knows that certain very young ladies exist, it nevertheless ignores them until they make their entree in due form, after which every one knows them, just as the reading world knows helium.

The existence of our debutante has been semi-officially recognized for some time. In 1872, Professor Norman Lockyer discovered in the chromosphere of the sun a bright, sharp, yellow line, the position of which is designated D 3, 587·45 wave length, and which apparently belonged to no element. It therefore indicated the existence of a new element, which he named helium, from its then only known home. Thus while there were strong probabilities that the new element helium existed, its non-discovery among the gases and minerals of the earth naturally led the majority of scientists to regard helium as a hypothetical or pre-debutante element.

Under the normal conditions helium is a gaseous element: its discovery following so closely that of argon, which is a compound and not an element, as I demonstrated in my article on argon published in the SUPPLEMENT, p. 16162. Helium is sure not only to become a popular gas, but also more popular than argon, for the reason that it will be connected with the subject of temperature, as will be shown later on.

The discovery of helium was purely accidental and is somewhat of a joke on a chemist connected with the United States geological survey. In a monograph published by this department, this chemist asserted that nitrogen is found in all uranium minerals. While working on argon, Professor Ramsay, in looking up the literature of nitrogenous substances, had his attention directed to the above monograph. He concluded to make the experiment himself and chose a rare uraninite called clevite. The extracted gas which he obtained was found to be a mixture of argon and helium, because it gave the spectroscopic lines of these two gases. The joke lies in the fact that by using apparatus not subject to leakage and by observing the ordinary precautions, neither Professor Ramsay nor any other English chemist has been able to obtain nitrogen from any uraninite.

So far as I know, helium gas has not been experimented upon enough to give any of its physical properties. But from a consideration of the same series of curves of the elements spoken of in my article on argon, of which three are shown in the following diagram, viz., the curve of sp. gr. variation, the curve of boiling point variation and the curve of melting point variation, I feel justified in predicting its physical qualities as follows:

It is a gas of a metallic element, which when solidified will have a color between that of iron and nickel and which will be more than eighteen times lighter than aluminum, the specific gravity being 0·14. It is the second element on the curve and in the periodic series, forming with hydrogen and americanum the first periodic series. Its atomic weight is very low, being 2. It will probably form numerous compounds with the other elements, but they will not be so stable nor so many as those formed by hydrogen. Probably a small percentage of some of these compounds may, like argon, be playing hide and seek in other gases supposed to be pure; if this is so, the discrepancies in the atomic weights, by which they vary slightly in whole numbers, may disappear.

Another physical property of helium, and the one which, as I have above stated, will make it a noted gas, is the temperature of its melting point, −242° C., and its boiling point, about −150° C. Owing to lack of data, only portions of the curve of the boiling (liquefying) points can be constructed, and these but crudely. The curve of the melting points shows that hydrogen melts (solidifies) at 90° C. lower than helium. This difference of temperature between the melting points of these two metals, as shown by the curve, does not seem to be too great when judging by analogy of the same difference of temperature for the elements from lithium to carbon, and from sodium to silicon.

But this melting point of hydrogen, −332° C., as shown by the curve, is 56° below the accepted absolute zero point of temperature. Is the melting point of hydrogen as above shown by the curve incorrect, or are the current conceptions in regard to the absolute zero point faulty?

Professor Olszewski has just succeeded in liquefying hydrogen in a quantity sufficient to determine its boiling point, which he states to be −243° C. The difference between this experimentally determined boiling point and the melting point as given by the curve is 89°. Taken in connection with the foregoing, the question, Is the above difference of temperature too great? becomes a very important one.

No one can tell where the frenzy of experiment which has seized the scientific world may end, or what revolutions in science are impending. But at the present time it seems highly improbable that we will ever be able to solidify hydrogen. We must therefore look for indirect testimony bearing on the point, since the direct is denied us.

Now, hydrogen is a metal, and if its physical properties are like those of the other metals, particularly like those on the upper loops of the curves of the elements (the first half of the periodic series), its melting point ought to be much farther below its boiling point than the melting points of nitrogen and oxygen (two of the "semi-permanent" gases) are below their boiling points −20° for nitrogen and −47° for oxygen.

Since the accepted absolute zero point of temperature is about 30° below the boiling point of hydrogen, then from the above deductions we can infer that the absolute zero point is as yet uncertain.

Just here is where the new element will come into play and help to settle this important scientific question. Helium is a contiguous metal to hydrogen on the curve and in its genesis. The chemical and physical properties of these two elements probably show more of a similarity than that between the alkali and the alkaline earth elements. Therefore the difference of temperature between its liquefying and its solidifying points will be very nearly the same as the difference between the same points of hydrogen.

The curve shows, approximately, that the liquefying point of helium is about −150° C. As this point is far above the liquefying points of nitrogen and oxygen (194 and 181), its liquefaction will no doubt be very readily accomplished.

The curve makes the solidifying point of helium just below the now known liquefying point of hydrogen. If the curve value of the solidifying point of helium is correct, it is possible to solidify it. Even if it is not quite correct, as long as the difference of temperature between its liquefying and solidifying points is more than the difference between the liquefying point of hydrogen and the absolute zero point, it will show that the solidifying point of hydrogen is below the so called absolute zero point, and in the region of the unknowable.

But are the accepted conceptions in regard to the absolute zero point of temperature correct? By referring to the article Heat in the Encyclopædia Britannica, it will be seen that the leader of science, Lord Kelvin,

SCALE : ATOMIC MASS 1 INCH PER UNIT
SPECIFIC GRAVITY 2 " " ■ "
TEMPERATURE " " 2.00°C
ZERO POINT OF TEMPERATURE = −432°C
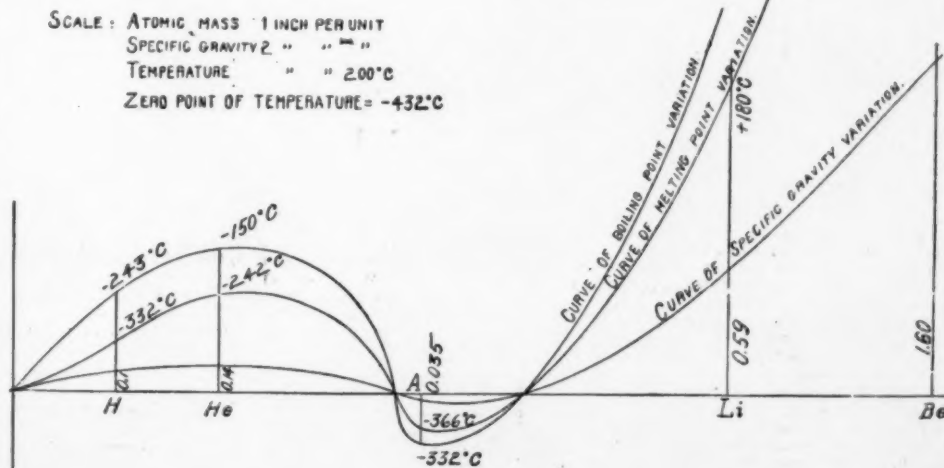
THE NEW ELEMENT HELIUM.

makes the absolute zero point by refined calculations to be exactly —273·10° C.

This result is arrived at by considering the change of volume of a substance for an increase or decrease of 1° of temperature to be the same over the whole range of temperature. But this change of volume occurring with a change of temperature, the formulation of which is known as Boyle's law, is known to be only approximately exact. Besides, near the points of physical change—the melting, boiling, dissociating and critical points—the variation from Boyle's law is quite pronounced.

Besides formula 3 in the above article, on which Kelvin lays great value, for the above reason becomes uncertain when approaching two points and indeterminate when these points are reached. One point is the (upper) critical point of water, above which water can only exist as steam, 720° C.; the other point is at about —196° C., where ice ceases to covered by a zone of its own vapor.

It is a recognized fact that every substance is surrounded by a zone or shell of its own vapor, or by a zone of some other gas. In the latter case, if the substance is sufficiently heated, the gas will be displaced by its own vapor. This point at which the vapor commences to form or to disappear, according as the body is being heated or cooled and which so far has received no attention, I call the lower critical point; the other well known critical point I call the upper critical point.

Water sustains an appreciable tension of its own vapor at —40° C. (about 0·1 mm.), and from my calculation this tension does not entirely disappear (reach the lower critical point) until about —196° C. The difference of temperature between the solidifying point and the lower critical point naturally varies for each substance. For hydrogen we will probably be within bounds if we assume this difference of temperature to be one-half of that of water, or about 100°. This would make the lower critical point of hydrogen —432° C. In fact, I arrived at this figure by a calculation which cannot be given here.

If the above reasoning is correct, then we not only can push our temperature investigations 159° C. below the accepted absolute zero point of temperature into a terra incognita, but we can also say that there is apparently no finite inferior limit of temperature; for it is evident that hydrogen can exist as a solid far below its lower critical point, just as gold, platinum, glass, etc., exist below their lower critical points, which are above the normal atmospheric temperature.

Although the melting point of americanum, the third element, is 34° lower than that of hydrogen, its lower critical point probably lies above —432° C. Then, since we must have some starting point from which to make our temperature measurements, we can, in a limited sense, call the lower critical point of hydrogen —432° C., our zero point of temperature.

Dr. W. H. MASSER.

[Continued from SUPPLEMENT, No. 1015, p. 16221.]

THE CARBIDES AND ACETYLENE COMMERCIALLY CONSIDERED.*

By T. L. WILLSON and J. J. SUCKERT, Ph.D.

COMMERCIAL APPLICATION.

HAVING described the physical and chemical properties of calcium carbide and the product of its decomposition with water—acetylene—we will now consider the commercial possibilities of these compounds.

Carbide of calcium, as we have already shown, is a rich source of acetylene, but beyond this we cannot at present definitely designate additional commercial applications of this material.

Extended experiments are now being conducted to determine its commercial value in the production of cyanides and various nitrogenous compounds, in the manufacture of iron, steel, and other metals, and their alloys, and in its application to the synthetical formation of various organic compounds.

The results thus far obtained, however, although encouraging, do not as yet justify us in accepting them as commercially applicable.

As the commercial value of any material largely depends upon its cost of production, its purity, and the value of the products and by-products obtained therefrom, our first consideration will be the method of manufacturing the carbide of calcium and the cost of the finished product.

The carbide of calcium originally prepared by Mr. Willson during his first experiments was produced at a cost largely in excess of that for which it can be manufactured to-day, but a description of these original experiments will, without doubt, be of interest to you.

The first experiments were made with a dynamo generating a current of 150 amperes at from 60 to 70 volts. The furnace consisted of a plate of carbon 12 inches square and 1 inch in thickness, along one edge of which an iron rod was bolted and projected beyond the mason work, and to which one terminal from the dynamo was connected. This carbon plate was embedded in brickwork, having only a small central portion exposed, upon which the graphite crucible rested. From one terminal of the dynamo the current was conducted through the iron rod, carbon plate, graphite crucible, the material to be acted upon, and the carbon pencil, to the other terminal. To start the furnace, the pencil was placed in contact with the bottom of the crucible and the dynamo was started up slowly. As the electromotive force increased, the pencil was withdrawn from the bottom of the crucible and the "arc" established.

The material to be acted upon was then introduced through an opening in the cover of the crucible, the cover being either of non-conducting material, or, if of graphite, insulated from the crucible by a non-conducting luting. One of the pencils from the original lot used in these earlier experiments is now before you. This carbon pencil is 12 inches long, 1¼ inches in diameter, copper-plated, and has a hole bored through its entire length, the tube so formed being used for the introduction of gaseous agents. With this furnace various metallic compounds, intermingled with pulverized carbon and also surrounded by gaseous reducing

agents, were subjected to the intense heat developed by the electric arc.

The success attending the operation of this first furnace, in the reduction of refractory metallic oxides, justified the continuation of the experiments upon a larger scale, and to this end the Willson Aluminum Company was organized and a plant erected at Spray, N. C. This plant was supplied with a dynamo, operated by water power, and generating a current of 2,000 amperes at 35 volts. The furnace was constructed as here shown (Fig. 8), namely:

A designates the outer masonry shed or bench of the furnace; B, the carbon or graphite crucible or hearth; C, the carbon bar or pencil constituting movable electrode; and D, the dynamo for generating the
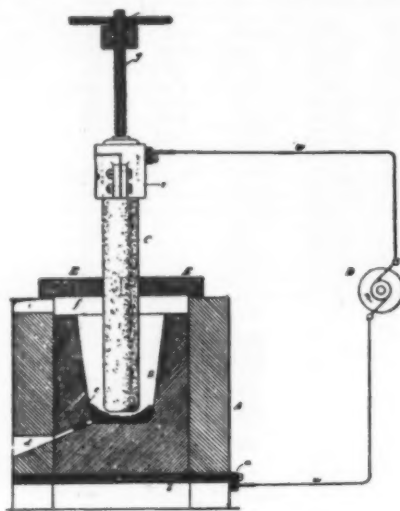
FIG. 8.

current. From the terminal brushes of this dynamo, one wire, w, leads to and communicates with the crucible, B, while the other wire, w', leads to and communicates with the carbon pencil, C. The connections are usually made in the manner shown, the wire, w, being connected through a fastening bar, a, to an iron plate, b, underlying the crucible, B, and the wire, w', being connected to a metal socket, c, embracing the upper end of the carbon pencil, C. The bench, A, is generally made of firebrick, which is a non-conductor of electricity, and the furnace is covered with a plate or, preferably, two plates, EE, of carbon, having a central hole, through which the carbon pencil, C, projects down into the crucible.

For tapping out the resulting product, a tap hole, d, is formed which, in operation, is closed by a plug, e, of clay or other suitable refractory material. The carbon plates, EE, rest on the top of the firebrick walls, A, which project above the top of the crucible forming an intervening space, f, for the furnace, between B and E. For the vertical adjustment of the carbon pencil a screw-threaded shaft, g, is provided, which may be moved up and down by the engagement therewith of a suitably mounted rotative nut, h.

The first carbide of calcium produced in this furnace, in accordance with memoranda taken at the time by Mr. Willson, was manufactured as follows: A mixture of lime and tar was boiled in a caldron, in the proportion of 60 pounds of lime to 11 gallons of coal tar, and the heating was continued until the mixture was perfectly dry. It was then introduced into the furnace and subjected to the heat of the electric arc for a period of two hours, gradually feeding the mixture of lime and tar to the furnace as fusion took place. The product obtained consisted of a purplish yellow mass, which, in contact with water, evolved acetylene gas. A sample of the calcium carbide produced upon this occasion is now before you, and represents the first calcium carbide produced in an electrical furnace.

The experiment was repeated with a mixture of 15 pounds of tar in fused lime and alumina, the time required for the operation being one and one-half hours.

The product obtained was a black, crystalline mass, consisting of a double carbide of calcium and aluminum. A sample of this double carbide is also submitted for your inspection.

Another run, made with a mixture of 10 pounds of lime and 10 pounds of finely divided carbon, operating one hour, resulted in the production of a dark, crystalline mass, showing at its fracture black and blue crystals. A small metallic ingot was found in this mass, and a similar ingot of this white metal is now before you.

A fourth test, made with 17½ pounds of lime and 17½ pounds of carbon, resulted in obtaining 11 pounds of almost pure calcium carbide.*
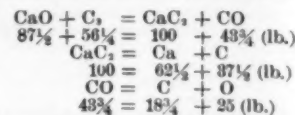
The tests described represent but a few of the numerous experiments conducted by Mr. Willson in his efforts to successfully and economically produce calcium carbide on a large scale. Recent results in the application of the alternating current to its manufacture prove conclusively that calcium carbide, of a remarkable purity, can be commercially produced. The product now being manufactured, in quantities exceeding one ton per diem, will readily evolve in contact with water 5¾ cubic feet of acetylene gas per pound of the carbide used, a result closely approaching to that which is theoretically possible, namely, 5 89-100 cubic feet per pound of carbide.

The theoretical proportions of lime and carbon required for the production of 100 pounds of calcium carbide are 87½ pounds of lime and 56¼ pounds of carbon.

Of the latter 37½ pounds combine directly with the metal calcium; and 18¾ pounds combine with the oxygen of the lime, and escape from the furnace as carbon monoxide, in accordance with the following formula:

$$CaO + C_2 = CaC_2 + CO$$
$$87½ + 56¼ = 100 + 43¾ \text{ (lb.)}$$
$$CaC_2 = Ca + C$$
$$100 = 62½ + 37½ \text{ (lb.)}$$
$$CO = C + O$$
$$43¾ = 18¾ + 25 \text{ (lb.)}$$

A further element of cost in its manufacture is the production of heat in the furnace by means of the electric arc. Extended experiments in this direction have shown that one electrical horse power will readily produce twenty pounds of calcium carbide each twenty-four hours, and the present indications justify the assumption that with automatically fed furnaces, properly insulated to retain the heat, and by utilizing the waste heat to increase the temperature of the material acted upon, the production of calcium carbide can be increased on a large scale to thirty pounds per electrical horse power each twenty-four hours.

By using limestone and coal dust, the latter being practically a waste product (not at present utilized), it is believed that calcium carbide can eventually be produced at a cost of less than $5 per ton. Where bituminous coal is employed, the value of the by-products obtained by its conversion into coke will largely reduce the cost of manufacture.

The hydrate of lime obtained from the decomposition of the carbide with water can be used again in the manufacture of the carbide, or it can be employed in the manufacture of ready mixed mortar, which is already quite an industry in this city.*

Arrangements are now being made by the Electro-Gas Company, of New York City, with the Niagara Falls Power Company, to apply 1,000 electrical horse power to the manufacture of calcium carbide, which is shortly to be increased to 5,000 horse power, and, eventually, we will, without a doubt, see the entire available power the company now possesses converted into electrical energy for the manufacture of this product. The effect of such a production would be far-reaching, and the economies resulting therefrom, if stated to-night, appear exaggerated and visionary. Assuming that but 20 pounds of the carbide are produced per indicated horse power each 24 hours, then the amount manufactured during 300 working days would be 3 tons per horse power per year; and applying 100,000 horse power to its production, the annual output of such an establishment would be 300,000 tons. From this amount of material 3,300,000,000 cubic feet of acetylene gas should be produced, and as its illuminating power, compared with ordinary illuminating gas of 25 candle power, is as 10 to 1, it would represent fully 33,000,000,000 cubic feet of this gas—an amount which would probably equal the annual output of the entire gas industry of the United States.

As this is but one of the many applications of the product obtained by the decomposition of the carbide with water, the manufacture of the carbide itself must, of necessity, become a large industry.

As we have previously informed you, pure calcium carbide contains, in 100 parts, 37·5 parts of carbon and 62·5 parts of calcium, and when brought in contact with water, acetylene is generated to the extent of 5·89 cubic feet of the gas to each pound of carbide used; or if compared by weight, 100 pounds of calcium carbide and 56·25 pounds of water evolve 40·63 pounds of acetylene gas, and form 115·62 pounds of calcic hydrate, in accordance with the following formula:

$$CaC_2 + 2H_2O = CaOH_2O + C_2H_2$$
$$100 + 56·25 = 115·62 + 40·625 \text{ (pounds).}$$
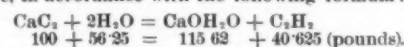
The acetylene gas so generated contains, in 100 parts, 92·3 parts of carbon and 7·7 parts of hydrogen, or in the 40·625 pounds generated from 100 pounds of carbide we have 37½ pounds of carbon and 3½ pounds of hydrogen. The entire carbon contained in the calcium carbide has, therefore, combined with the hydrogen of the decomposed water to form a new compound of a gaseous nature and extremely rich in carbon.

In its commercial application acetylene can be produced either directly from the calcium carbide by decomposition with water, or it may be evolved from the liquefied gas contained in suitable receivers.

When manufactured directly from the carbide, two

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* A sample of the carbide obtained during this last test was sent by Mr. Willson to Lord Kelvin, of the Glasgow University, and, in return, the following reply was received:

"The University, Glasgow, October 3, 1892.

"Dear Sir: I have seen and tried the calcium carbide, only, however, so far as throwing it into water and setting fire to the gas which comes off. It seems to me a most interesting substance, and I thank you very much for sending it to me. Yours very truly, "KELVIN.
"Thomas L. Willson, Esq."

* The following details of the cost of producing 150 tons of calcium carbide per diem, as a by-product in the manufacture of 100,000 fire and pressed brick per diem, will, no doubt, interest you.

The figures were compiled by a manufacturer who was desirous of commercially utilizing the close proximity of large deposits of coal, limestone, and clay. They show an annual profit of $625,640, with a selling price of $7 per ton for carbide.

January 19, 1895.

PRODUCT OF 1,400 TONS OF COAL, 450 TONS OF CLAY, AND 270 TONS OF LIMESTONE.

150 tons of calcium carbide, at $7	$1,050 00
10 tons of sulphate of ammonia, at $70	700 00
40 tons of coal tar, at $7	280 00
910 tons of coke, at 90 cts.	819 00
50,000 fire brick at works, at $15	750 00
50,000 dry pressed front brick, at $15	750 00
	$4,349 00

5,445,000 FEET OF RICH ILLUMINATING GAS.

3,240,000 feet of this will produce 12,000 horse power for 24 hours, allowing 13½ pounds coal per horse power, and 9 cubic feet of gas as the equivalent of 1 pound of coal. 1,485,000 cubic feet of gas will burn 270 tons of limestone, producing 150 tons of lime, allowing 1,100 pounds of coal per ton of lime, and 9 cubic feet of gas as the equivalent of 1 pound of coal. 720,000 cubic feet of gas will burn 100,000 bricks, allowing 800 pounds of coal per 1,000 bricks.

EXPENSES.

Mining 1,400 tons of coal, at 55 cts.	$770 00
Mining 450 tons of clay, at 35 cts.	157 50
Mining 270 tons of limestone, at 25 cents.	67 50
Labor on 1,000 tons of coke, at 20 cts.	200 00
Freight on 210 tons of limestone, at 50 cents.	135 00
Labor in grinding 150 tons of lime, at 25 cts.	37 50
Labor in making 100,000 brick, at $2 per M.	200 00
Labor in smelting calcium carbide	150 00
	$1,717 50
Twenty-five per cent. on $1,717.50 for general expenses.	429 37
	$2,146 87
Interest on plant per day	83 33
	$2,230 20
Income	$4,349 00
Expenses	2,230 20
Net income per day	$2,118 80
Net income per year (300 days)	635,640 00

methods can be employed; in one, small quantities of water are allowed to flow upon the carbide and the resulting gas is conducted to an ordinary gasometer, from which it can be drawn for use; this method is more or less intermittent. The other method dispenses with a gasometer and permits the continuous generation of either large or small quantities of the gas, and this is accomplished by partially submerging in water a vessel open at the bottom and containing carbide suspended on a screen in the upper part of the vessel, the generated gas being withdrawn from above the carbide. As long as gas is being used, the water remains more or less in contact with the carbide; as soon, however, as the withdrawal of gas diminishes or entirely ceases, the pressure of the generated gas forces the water from the carbide into the lower chamber of the vessel, thereby preventing a further generation of the gas. The apparatus is automatic and extremely regular in its operation.

In the employment of either of the above methods, the only by-product obtained is slaked lime, the amount of gas produced being the same, namely, 5½ cubic feet for each pound of calcium carbide used.

The liquefied gas is manufactured commercially by decomposing the carbide of calcium with water in a closed vessel, and conducting the gas generated under pressure to a condenser, where it liquefies and is then drawn off in tanks ready for distribution.* The liquefied gas exhibited this evening has been produced in this manner.

Before entering upon the use of acetylene as an illuminant, we desire to call your attention to the fact that its rapid and extraordinary development in this direction is largely due to the individual efforts of Mr. E. N. Dickerson, of New York City, who, endowed with a special knowledge of the subject, has labored unceasingly to bring about the successful result which you will see this evening.

As an illuminant, acetylene surpasses in lighting power and economy all other illuminants known; when burned at the rate of five cubic feet per hour, it produces a light equal to 250 candles, whereas the best illuminating gas made from coal or water gas rarely exceeds twenty-two candles for each five cubic feet burned per hour. Your Philadelphia city gas is rated at from nineteen to twenty candles. Acetylene gas will, therefore, produce twelve and one-half times more light if the same quantity be consumed, or 1,000 cubic feet of acetylene gas will give you the equivalent in lighting power of 12,500 cubic feet of your city gas; it has, therefore, twelve and one-half times the value. To illustrate more fully the difference, we will first pass your city gas to the tube attached to this stand, and ignite the gas as it issues from the burners, we then conduct acetylene gas to a similar row of burners, and light these; the contrast, as you will perceive, is almost marvelous.

The acetylene consumed in these burners has been generated, in the apparatus before you, in the following manner: Upon the carbide contained in this closed jar (Fig. 9), water is poured in small quantities through the glass funnel communicating with the interior of the jar. The acetylene gas generated passes through this tube to the inside of the gasometer, thereby lifting the holder to the position which it now occupies, and the gas can then be conducted from the holder to the burners by means of this rubber tube. As the gas is being consumed and the holder lowers, the supply is rapidly renewed by pouring an additional amount of water through the funnel upon the carbide contained in the closed jar. We will also light the gas produced from liquefied acetylene con-

pressure, as the gage now indicates, of forty atmospheres, passes from the tank to a reducing valve upon which the tank stands, whereby its pressure is reduced to that of a two-inch water column, as indicated on this U water gage, and it is under this pressure that we are supplying the gas to the burners attached to the arm above. Each of the burners supplied with acetylene gas will consume, at the pressure indicated, 1¼ cubic feet per hour; each, therefore, emits a light equal to sixty candle power; the total candle power of the six burners in use is, therefore, 360, and the amount of gas consumed each hour 7½ cubic feet. To
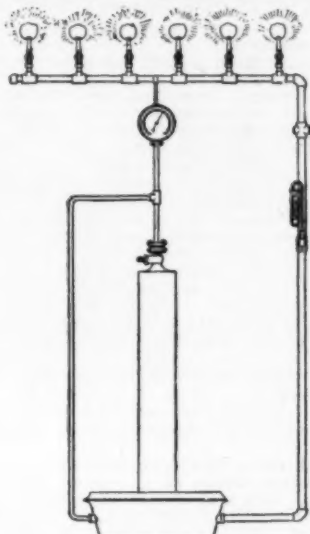
FIG. 10.

obtain this result with city gas would require the consumption of at least ninety cubic feet per hour.

The amount of oxygen withdrawn from the atmosphere of this room by the acetylene for the same amount of light is but one-sixth of that required for your city gas; the products of combustion are, therefore, reduced in proportion and the air of the room is not vitiated to the same extent.

From the appearance of the acetylene flame it would seem as though its temperature was exceedingly high; but recent determinations have shown that the temperature of the flame does not exceed 900° C., whereas the temperature of ordinary illuminating gas exceeds 1,400° C. For an equal amount of light the heat developed by the combustion of acetylene gas but slightly exceeds that of the incandescent electric lamp.

We have before us to-night, therefore, an ideal illuminating gas; its presence in a room can readily be detected by its penetrating odor; it emits more light with less heat than any other illuminating compound; it consumes less oxygen and it can be commercially produced at less cost, for an equal amount of light. Furthermore, it is capable of being stored either as a solid, in the form of carbide, or as a gas, or as a liquid; and
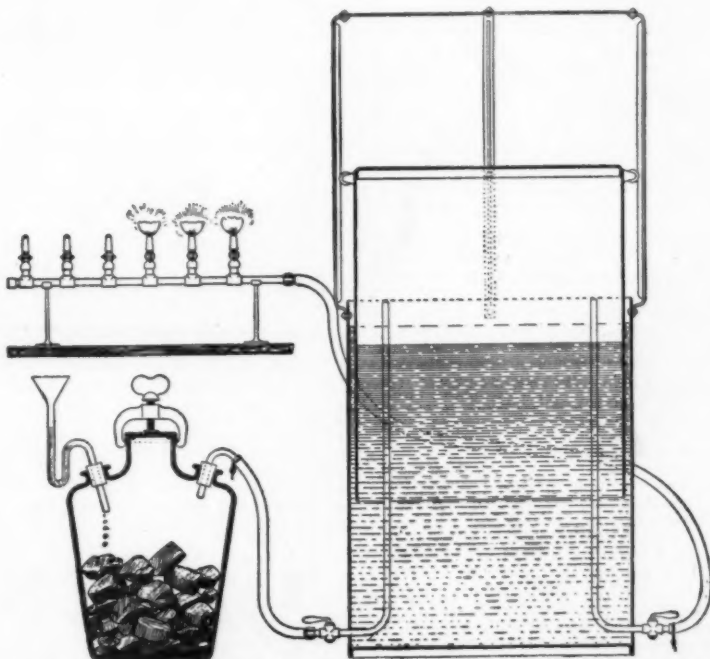
FIG. 9.—APPARATUS FOR THE MANUFACTURE OF ACETYLENE FROM CALCIUM CARBIDE.

tained in this small tank (Fig. 10), and, as you observe, it burns with the same brilliancy and lighting power as the gas produced directly from the carbide.

The liquefied gas contained in the small tank weighs just two pounds, and is capable of generating twenty-nine cubic feet of acetylene gas, which is at the rate of fourteen and one half cubic feet per pound. The gas produced by the vaporization of the liquid at a

these qualities alone are of exceptional value in its commercial application.

As a solid, in the form of carbide, waste water power throughout the world can be utilized for its manufacture, and it can be shipped long distances without material deterioration. As a gas, it can be generated from carbide and applied as such; and in the form of a liquid, it can be applied to all purposes of isolated lighting, such as railroad and street cars, carriages, bicycles, steamships, sailing vessels, street lighting, by placing a small tank in each lamppost (see Fig. 2), house lighting (in both city and country), buoys,

lighthouses, lanterns, and to the enriching of ordinary illuminating gas in dwellings. Its application to this latter purpose will permit the gas companies to produce a low priced gas for heating purposes, which can then readily be enriched in each house with acetylene gas generated from a tank of the liquefied gas. To show the value of acetylene gas if applied to the lighting of your city, we will make a comparison, which may surprise you. The amount of gas produced by your city works will approximate 4,000,000,000 cubic feet per year, of, say, twenty candle power. By the use of acetylene gas, the amount of gas required would be reduced in the proportion of 1 to 12·5; or, 4,000,000,000 cubic feet of city gas could be replaced by 320,000,000 cubic feet acetylene gas, representing a saving of 3,680,000,000 cubic feet of gas annually.

In addition to its value as an illuminant, acetylene gas can be used commercially for power and heating purposes; and in the form of a liquefied gas it will be invaluable for such use. Its application in this direction is, however, such an extensive one that we are compelled to make it the subject matter of another paper. In conclusion, we desire to thank you all for your kind attention, and especially the officers and members of the Franklin Institute, for the interest they have manifested in our work.

MATZOON.

By H. J. PATTERSON.

MATZOON is a fermented drink that has been quite recently brought to the attention of the American trade. It is made from cow's milk by a special process of fermentation and is the drink of the Armenians and Turks which corresponds to the koumiss (fermented mare's milk) of the Tartars, and the kephir (fermented sheep's and goat's milk) of the inhabitants of Caucasus.

Matzoon has about the consistency of thick cream, is white in color and effervescent. It has a sharp, acid taste, with a flavor something like that of buttermilk and a slight odor of yeast.

Matzoon is prepared in Maryland and New Jersey by Iskiajan Brothers (Armenians), and placed upon the market in ordinary pint beer bottles, tightly corked. The labels on the bottles bear the inscription "Sultan's Matzoon," and in order to show the esteem with which this drink is regarded in the Orient, the quotation "Oh my darling Sultana, thou art as precious in the harem as thy delicious matzoon among drinks" is also added.

As a rule matzoon would not be found perfectly agreeable to the ordinary taste, at first; but as for most such things, the taste is soon acquired and many persons grow fond of it, and find it a refreshing, nourishing and healthful drink.

The composition of matzoon is as follows, the sample examined being about four or five weeks old:

Specific gravity	1·0254	
Sp. gr. after expelling CO₂	0·9940	
Water	87·79	per cent.
Alcohol	0·55	"
Carbon dioxide	0·27	"
Solids	11·39	"
	100·00	

COMPOSITION OF SOLIDS.

Albuminoids	3·29	per cent.
Fat	4·25	"
Lactic acid	3·01	"
Sugar	Trace.	
Ash	0·84	"
	11·39	"

For comparison the following table has been compiled giving the composition of the different fermented milk products which have been referred to:

	Matzoon.	Koumiss.* (Cow's milk.)	Koumiss. (Cow's milk.)	Koumiss. (Mare's milk.)	Kephir.
	P. c.	P. c.	P. c.	P. c.	P. c.
Sp. gr.	0·994				
Water	87·79	89·32	88·93	91·53	91·21
Alcohol	0·55	0·76	2·65	1·85	0·75
Carbon dioxide	0·27	0·83	1·03	0·88	
Lactic acid	3·01	0·47	0·79	1·01	1·02
Albuminoids	3·29	2·56	2·03	1·91	3·49
Fat	4·25	2·08	0·85	1·27	1·44
Ash	0·84		0·44	0·29	0·68
Sugar	Trace	4·38	3·11	1·25	2·41

* American koumiss analysis by Wiley.

From this table it will be seen these different products are very similar in composition and that the only marked difference of matzoon from the others is found in the more complete transformation of the sugar into acid. Md. Agr. Exp. Station.—Agricultural Science.

[FROM THE NEW YORK SUN.]

SMOKELESS GUNPOWDERS.

By HUDSON MAXIM.

SEVERAL years ago, when smokeless powders were being introduced, and competitive tests were made mainly between them and the old forms of black and brown powders, it was easy to meet the ballistic requirements imposed. Now, however, all this is changed. The high ballistic results attained by recent smokeless powders, together with the knowledge gained from experience as to the importance of absolute stability of nitro-compounds entering into their composition, have tended to place the present standard of excellence for a smokeless powder very high indeed. To be considered satisfactory to-day, a smokeless powder must have a reputation for stability based upon tests severe enough to place that quality above question, and it must give ballistic results that were formerly deemed impossible.

Experience in the use of smokeless powders has developed many things not at first anticipated, and the knowledge from which have been evolved the best

* A full description of this process and of the apparatus required therefor is contained in U. S. patent No. 535,944, March 19, 1895.

powders of the present time has been costly. Formerly, the main object sought was the attainment of high ballistic results. The importance of the effect of the gases of combustion upon the bore of the gun was not recognized, but as powders containing very large percentages of nitroglycerine were introduced, and many large and valuable pieces of ordnance were destroyed, the question of erosion became a serious matter. At the present time the problem is the production of a powder which will produce as high ballistic results as possible, work the minimum injury upon the gun, and be a perfectly stable compound adapted for guns of all sizes.

Perfect preliminary washing and cleansing of the nitro compounds entering into a smokeless powder is not a sufficient safeguard against spontaneous decomposition. It is necessary that some neutralizer should be added; that is, a substance whose function is to combine with any nitrous acid that may in time be evolved or disengaged by any contingent reaction. Ordinary alkaline substances are not well adapted to the purpose, as they do not combine directly with nitrous acid in the absence of water. An ideal substance for the purpose appears to be urea, which combines directly at all temperatures with the smallest trace of nitrous acid the instant it is evolved in any compound where the urea is present. Furthermore, as the products of the reaction of urea with nitrous acid are water and carbonic acid, no new or deleterious compound is left in the powder. Even when unstable or insufficiently washed materials are used, a nitro-compound may be rendered perfectly stable by the addition of a quantity of urea sufficient to neutralize all acid not eliminated by washing and leave a slight excess of urea in the final product.

In the early smokeless powders, especially those made of compounds of soluble pyroxylin and nitroglycerine, it was supposed that the nitroglycerine actually held and retained the pyroxylin in solution, but it has since been learned that the nitroglycerine is held by smokeless powders, whether made with high or low grade guncottons, in much the same manner as water is held by a sponge; in fact, the pyroxylin exists in smokeless powder in the shape of a very minute sponge-like substance, within the pores of which the nitroglycerine is held in a free state. It is possible even with powders containing as little as 25 per cent. of nitroglycerine to squeeze out the nitroglycerine in a pure state, by subjecting a piece of the powder to great pressure between two smooth steel plates. Nitroglycerine was formerly supposed to be practically a non-volatile substance, but it has since been learned that it evaporates, though slowly, at all temperatures. All fine-grained smokeless powders, such as rifle and shot-gun powders, containing percentages of nitroglycerine, lose a considerable weight on long exposure, owing to their fine state of division; and as the loss of a small percentage of nitroglycerine will greatly vary the ballistic results of smokeless powders, this is a very important item to be considered.

With cannon powders, which are made in large grains or pieces, exposing a comparatively small surface for evaporation, the disadvantages due to this cause are reduced to a minimum. The tendency to evaporate is also enormously reduced by lessening the percentage of nitroglycerine employed. This objection cannot be sustained as against cannon powders containing a low percentage of nitroglycerine.

There is another serious objection to the use of nitroglycerine in powders for small arms, such as rifles or shotguns, even when a very small percentage is employed. Persons susceptible to the effects of nitroglycerine or nitrous fumes are very quickly prostrated with severe headache, and soldiers using such powder in the field are soon overcome by the fumes caught in the face in opening the breech of the gun and by the gases of incomplete combustion blown back upon them or enveloping them in action.

The most perfect gunpowder is that which most fully meets the following requirements, namely: It should impart maximum velocity to the projectile, with minimum pressure, and the pressures and velocities should be uniform when like charges are fired. It should be smokeless and leave no residue in the gun. It should not be friable or soft, but firm and hard, so that it will not disintegrate or break up in handling. It should be non-hygroscopic or unaffected by moisture. It should be perfectly stable and undergo no change under the varying temperatures of different climates. Its products of combustion should be so low in temperature as to cause a minimum heating of the gun, and of such a character as to cause little deterioration of the bore of the gun. All powder should be burned before the projectile leaves the gun, so that no poisonous nitrous fumes, due to imperfect combustion of the powder burning under atmospheric pressure, shall rise to affect the gunners.

To be smokeless, a powder must be consumed wholly into gases. To this end, the oxygen necessary to burn its carbon must be carried by some nitro-compound not having a metallic base; for when an oxygen-bearing salt, such as nitrate of barium, or nitrate of potash, is employed, as the nitrate of the metallic base is converted into a carbonate, there will be in the products of combustion solid matter in the form of smoke and residue in the gun, practically equal to the weight of such salt used in the powder. The most prominent smokeless powders heretofore produced have been compounds of guncotton with nitroglycerine or guncotton with some oxygen-bearing salts.

Although, broadly speaking, there are several hundred varieties of pyroxylin, usually called guncotton, but two varieties are generally recognized: first, trinitrocellulose, or high grade guncotton, sometimes called insoluble guncotton, because insoluble in a mixture of ether and alcohol; and, second, dinitrocellulose, or low grade and soluble guncotton, so called because soluble in a mixture of ether and alcohol.

The first smokeless powders brought out, such as those by Nobel and the French government, were compounds of soluble guncotton and nitroglycerine in varying proportions. My brother, Hiram S. Maxim, and myself were the first to bring forward as a smokeless powder a colloid of high grade guncotton, or a high grade guncotton dissolved and dried, and either combined or not with nitroglycerine. In 1889, 1890, 1891, we conducted in England and the United States very extensive experiments with both high and low guncotton, alone and in combination with nitroglycerine,

nitrate of barium, nitrate of potash, nitrate of ammonia, picric acid, and many other substances. We found that for stability and keeping qualities high grade insoluble guncotton was far superior to low grade or soluble guncotton, and that the keeping qualities of the high grade were maintained whether or not nitroglycerine was combined with it. We further found that, when a proper quantity of nitroglycerine was added to guncotton, very much more satisfactory ballistic results were obtained than when guncotton was used pure or combined with any of the other above-mentioned oxygen-bearing ingredients. We made smokeless powders from high grade guncotton containing from 5 to 60 per cent. nitroglycerine, and finally settled upon 25 per cent. as the most satisfactory proportion, all things considered.

Guncotton combined with any other substance to help it burn does not ignite or combust readily enough, or possess propelling power enough to give anything like as satisfactory results as are obtained when a small percentage of nitroglycerine is added. Furthermore, guncotton alone cannot well be made into rods or grains of any considerable size without warping and cracking to pieces in drying. However, by a recently patented multi perforating process, the powder may be made out of pure guncotton and dried without cracking, because the powder dries from the inside at the same time as from the outside. Although a cannon powder can now be made of pure guncotton, still it is preferred to employ a small percentage of nitroglycerine in combination to facilitate ignition and combustion, secure higher ballistic results, and at the same time lessen the difficulties of manufacture.

Present results indicate that a high grade guncotton powder containing about 10 per cent. nitroglycerine is best, all things considered, and I believe it to be superior to any other known compound that can be employed.

Excellent results have been had with cannon powders consisting mainly of guncotton, either high or low grade, with percentages of nitrate of barium varying from ten to forty per cent., the nitrate of barium being added to supply the guncotton with oxygen to facilitate ignition and combustion. But an objection to this powder is that it is not smokeless, owing to the nitrate of barium not being consumed into gases, whereas a powder consisting of guncotton and nitroglycerine contains only smokeless elements, and, when properly made, should contain just enough nitroglycerine to cause it to ignite and burn readily and to facilitate its manufacture.

The high velocities and comparatively low pressures obtainable with smokeless powders containing a large percentage of nitroglycerine are due to the large volume of gases and the enormous heat evolved by the nitroglycerine in combustion. This great heat of combustion in connection with the high specific heat of the gaseous water produced and forming a large percentage of the gases, gives the products of combustion of nitroglycerine a tremendous expansive power above that of any other ingredient that can be employed in a smokeless powder. This fact, coupled with the great increase in rapidity of combustion as the powder becomes heated in burning, has given nitroglycerine an excellent reputation as a constituent of smokeless powder from a ballistic standpoint.

Furthermore, the ease and cheapness with which a colloid of guncotton containing large percentages of nitroglycerine can be made, and the great difficulty and increased expense of making powders with a small percentage of it, have caused nitroglycerine to be used in excessive quantities, on account of which its great ballistic value has been offset by the following disadvantages:

The great heat and density of the products of combustion of nitroglycerine and their richness in oxygen cause them to work destruction on the bore of a gun. The products of combustion of a smokeless powder containing a large percentage of nitroglycerine contain much more carbonic acid gas and gaseous water than those of a powder containing a small percentage of that compound and a larger percentage of guncotton. Nitroglycerine of itself contains more oxygen than is necessary to complete combustion into carbonic acid gas and water, while pure guncotton alone does not contain enough oxygen for complete combustion, so that its products of combustion contain a much smaller percentage of carbonic acid.

The elements of water are dissociated at a temperature of 1,000° Centigrade. Above that temperature the oxygen and hydrogen are merely a mechanical mixture. The products of combustion of powder in a gun are at a temperature very much above 1,000° Centigrade during the time the shot is in the gun. At high temperatures, and especially at high temperatures under great pressure, carbon and oxygen become extremely active in their affinity for each other. The oxygen in powder gases, therefore, being in a free state, the same as the oxygen in the air, it must unite with all carbon with which it comes in contact. The first step in the reaction of explosion of a nitro-compound is the combination of hydrogen with oxygen, setting free the nitrogen and carbon. As the temperature is simultaneously raised above the point of dissociation of oxygen and hydrogen, by the carbon in a nascent state attacking the oxygen and combining with it at the expense of the hydrogen, all the carbon is immediately taken up by the oxygen, and if there be sufficient oxygen, all of the carbon is consumed into carbonic acid. If there be insufficient oxygen to so consume the carbon, then a portion of the carbon combines with the oxygen to form carbonic oxide. It is not until the projectile leaves the gun and the temperature of the gases is lowered that the hydrogen recombines with the oxygen to form water.

Under the great heat and pressure the carbonic acid gas and gaseous water become oxidizing agents, and it is probable that the oxygen attacks the bore of the gun by combining with its carbon and converting it into wrought iron at the immediate surface of contact with the heated gases.

Of course this is only theory, but I believe it to be true; at any rate, it is certain that the rapid erosion of the gun, when there is any escape of gases past the projectile, is due to their great density and richness in oxygen and the high temperature of the gases. With guncotton powder a large proportion, in fact too large a proportion, of the products of combustion is car-

bonic oxide, which is a reducing agent, instead of an oxidizing agent. Furthermore, about one-half less heat is evolved in combustion to carbonic oxide than in combustion to carbonic acid gas, while carbonic oxide is much less dense than carbonic acid gas.

In favor of guncotton we, therefore, have the advantages that it does not attack the bore of the gun chemically, and its gases are so light and so low in heat that they have a minimum injurious or erosive effect upon the gun. In a powder having a small proportion, say 10 per cent., of nitroglycerine, the guncotton so largely predominates over the nitroglycerine in quantity that the compound still contains insufficient oxygen for complete combustion. If a high percentage of nitroglycerine is employed, as is usual with other nitroglycerine powders, the compound contains more oxygen than is necessary for its complete combustion. As there is always more or less leakage of gases past a projectile in its flight through the bore of a gun, I believe that high per cent. nitroglycerine powders must be abandoned because they rapidly destroy all guns in which they are used.

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